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The Implementation of Engineering Design Challenges on 4th Grade Students' Attitudes Towards Engineering, Classroom Climate, and Writing Ability

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THE IMPLEMENTATION OF ENGINEERING DESIGN CHALLENGES ON 4TH GRADE STUDENTS' ATTITUDES TOWARDS ENGINEERING, CLASSROOM CLIMATE, AND WRITING ABILITY

by

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ABSTRACT

The purpose of this study was to determine if my practice of having 4th grade students participate in engineering design challenges impacted their attitudes towards engineering, the classroom climate, and writing ability. In this action research students were given a pre and posttest that measured their attitudes towards engineering and their perceptions of the classroom climate. A pre and post written reflection was also examined and compared for the use of predicting, observing, thinking, explaining, reflecting, and yearning to learn more. A triangulation of data included the use of pre and posttest statistical analysis, rubrics, teacher observation, and student interviews. The data collected from this action research project showed that that students were more satisfied with the course after completing the design challenges, the classroom environment improved in that students perceived the level of friction in the class had decreased. The data collected also showed that students' attitudes towards engineers was changed in that they were more likely to want to pursue a career in engineering and take a future school course in engineering after having completed this action research. Student generated definitions of engineers demonstrated a decrease in the number of misconceptions about the work of engineers and an increase in students' knowledge as to what engineers do for a living. My practice of implementing engineering design challenges with a 4th grade class did not have an impact on students writing ability.

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CHAPTER ONE: INTRODUCTION

"Science, technology, engineering, and math (STEM) education is of the utmost importance to all students and is critical to U.S. competitiveness." U.S. President Barack Obama spoke these words on April 20, 2011. He stressed the fact that emphasizing STEM education is one of the most important efforts the US can take if it hopes to produce college and career ready students (as cited in eSchool News, 2011). The engineering component of STEM education was not a focus of the regular school day, but was taught in after school programs or as special projects. In the past, only elementary students who sought out courses in engineering were exposed to them. Elementary students should be a major focus of engineering education. This may serve to instill in them an interest in STEM subjects that can continue into the middle school, high school, and college years.

During the 2010-2011 school year, engineering design challenges were included in our science curriculum. I was excited about the idea of having my class produce technology and solve problems. The district offered a special training on how to implement these design challenges and I attended. I came back enthusiastic and even hosted a school wide training on the design challenges for the rest of the elementary teachers at my school.

My first attempt at implementing the design challenges was a failure. The challenge of building a wind powered car took over two weeks. Even though I spent two weeks completing this challenge, I was not satisfied with the outcome. I became frustrated as the students argued in their groups about how they were going to proceed in the challenge and I did not allow them time to reflect on their initial designs either orally or in writing. I denied my students the time and practice of refining and improving their design based on the observations they made during class.

At the end of the year I did a follow-up with my school's staff on the training I had given. While the teachers had seemed enthusiastic during the training, most of them had not attempted to complete the design challenges during science. The factors that they stated led them to omit this portion of the curriculum were time and management. They believed that the challenges would take too long for them to complete. One teacher stated she had to choose between teaching the science content or completing these building activities. Other teachers mentioned that the projects seemed too intensive or complicated for their students and that managing all the materials necessary to complete the challenges would have been overwhelming.

I served as one of the coaches for our middle school Science Olympiad team during the same year. Science Olympiad includes building events and testing events. I noticed that the majority of the students were reluctant to volunteer to compete in the building events. These were students who were interested enough to join a club in which the focus was science. They did not see the connection between science and engineering. The students who did compete in the building events were not confident in their ability to design, build, and test a piece of technology.

I wondered if these middle school students had been exposed to engineering during their elementary school years if their attitudes towards the building events would change. This thought encouraged me to try a different approach to implementing the engineering design challenges in my 4th grade classroom. If I was going to attempt to complete engineering design challenges in my classroom, I wanted to be sure that students had enough time to complete the entire engineering design process and reflect upon what they learned.

Purpose

The purpose of this action research was to determine how my practice of implementing engineering design challenges during a 4th grade enrichment block would impact students' attitudes towards engineering and technology.

Questions

When I decided to undertake introducing the engineering design process in the elementary classroom as an action research project there were three specific areas of interest that I wanted to focus on.

1. How did my practice of implementing engineering design challenges during a 4th grade enrichment class affect students' attitudes towards engineering?
2. How did my practice of implementing engineering design challenges during a 4th grade enrichment class affect the classroom climate in regards to collaboration?
3. How did my practice of implementing engineering design challenges during a 4th grade enrichment class affect students' written communication skills?

Rationale for the Study

Board of education rule 6A-6.054 states that immediate intensive intervention (iii or customized instruction) is mandatory for students who have been identified as having a reading deficiency and this time can be in addition to or as an extension of the 90 minute reading block (Department of Education, 2011). In 4th grade students are identified as requiring iii instruction if they scored a level 1 or a level 2 on the previous year's FCAT. A student who scored a level 1 or a level 2 on FCAT is considered to be academically below grade level. During the 2010-2011 school year, our school decided to implement a dedicated 30-minute block of time for immediate intensive intervention (iii) in grades K-5.

On our 4th grade team, two teachers were each given 10 students who required iii instruction. I was the teacher of the "bubble group". Students who were placed in the bubble group had scored a low level 3 on the previous year's FCAT. This means that they were considered on grade level. Based on county benchmark exams, these students had a very strong probability of dropping to a level 2, which is considered below grade level in 4th grade. The two remaining teachers on the team taught an enrichment class to all students who were predicted to score a level 3 or higher on the FCAT. During this enrichment class, students completed extension activities to the 4th grade curriculum.

The two enrichment classes focused on reading and math throughout the entire school year. Students played math games and completed an enrichment portion of our reading curriculum. The purpose was to expose these students to 4th grade reading and math benchmarks in a manner that involved problem solving and critical thinking. They were also required to complete research based on topics that were relevant to our reading themes and then produce power point presentations of their findings. The teachers of these groups stated that being able to conduct research and present their findings were skills that the students would need as they advanced through school. The two enrichment classes did not complete any activities based on science or social studies.

School administration stated that the enrichment class was not required to focus on reading and math. This was a time when students could be exposed to extension activities based on any of the 4th grade benchmarks. I thought this enrichment time would be the perfect time to explicitly teach the engineering design process that was now a part of our science curriculum.

Our new science curriculum is lab based. There is at least 1 lab or inquiry lesson for each of the 4th grade science standards. The culminating experience of each marking period is an engineering design challenge. Students are given a real world problem that they have to solve by creating a piece of technology.

Significance of Study

During my research on engineering education, I noticed a trend that many students entered middle and high school with engineering misconceptions. These misconceptions may lead students to have a negative view of engineering and their ability to perform in a class dedicated to engineering.

A survey of engineering employers stated that engineering graduates had several weaknesses, including lack of design capability or creativity, weak communication skills, and little skill or experience in working in teams (Prados, 1998). This immediately brought to mind some of the observations I had made with my own class during my first unsuccessful attempt at introducing the engineering design process. In particular, how students cooperated with each other while working as a group to produce a final product and the fact that I neglected to incorporate written communication of any kind within my instruction.

As work in national standards and curriculum in K-12 math, science, engineering, and technology are being developed, it is essential for research in engineering education to deepen our understanding of how students perceive engineers and the work they do (Capobianco, Diefes-Dux, Mena, Weller, 2002). Hester and Cunningham (2007) state that there are numerous reasons why elementary aged students should be introduced to an engineering curriculum. First, because of their interest in building, children are already “engineering informally.” Second, engineering can be used to integrate other subjects and help improve problem solving skills. Finally, learning about engineering will increase students’ awareness of and access to scientific and technical careers (Hester, & Cunningham 2007).

Lang, Cruse, McVey, and McMasters (1999) surveyed engineers and engineering managers about the most important skills they look for in engineers. The following skills were ranked of high importance: interpersonal (verbal, non-verbal, and written) skills, ability to write a concise business letter, technical writing, concise expository writing, concise expository writing of letters, ability to use sketching and illustrating to communicate technical information or concepts, ability to function on a team, to participate as a team member, participate as a member of a problem solving team, function of a team in team based reporting or project results, how to participate in developing team strategies, and ability to write a team based case-study report. These are skills that are not taught in the traditional engineering curriculum. They show that engineering employers are looking for the 21st century skills of communication (particularly written communication) and collaboration.

The Australian Association for Engineering Education (2003) stated that today’s engineers need to have strong communication and team work skills, but they do not. Graduates lack of communication skills and teamwork experience show the need to reform today’s engineering curriculum (Mills, Treagust, 2003). Henshaw, Lang, Cruise, MCvey, and McMasters (1999) reiterate the fact that the desirable skills of communication and collaboration are sorely lacking in recently graduated engineers. A recent Australian report states that engineering employers are seeking graduates who have 21st century skills that go beyond the standard paper degree; this includes an excellent level of skills in communication, decision-making, and teamwork (Riemer, 2002). The Dean of Engineering at Duke University was quoted by Riemer "engineers who are adept at communications have a considerable advantage over those who are not".

The National Academy of Engineering 2008 publication states that most students have a broad understanding that engineers "design and build things" but do not have a deep understanding of what engineers actually do. It was also stated that students have a positive impression of engineers, but many feel they are not "smart enough to become engineers," and see engineering as hard work. The publication states that the public has a poor idea of what engineers actually do on a day-to-day basis and that missing from current perspectives of engineers are the essential characteristics of creativity, teamwork, an ethic of care, and communication (National Academy of Engineering, 2009).

Lang, Cruse, McVey, and McMasters (1999) created a survey based on the Accreditation Board for Engineering and Technology Engineering Criteria and administered it to 420 engineers and engineering managers that represented fifteen aerospace and defense related companies. The survey instrument listed 172 skills, knowledge descriptors, and experiences and the respondents were asked to rank each in importance for an entry-level engineer on a scale of 1 (very low) to 5 (very high). In the category listing skills under the ability to function on multi-disciplinary teams the skills function on a team, participate as a member of a problem solving/decision making team, and function in team based reporting of project result was listed at a 3.7. Participation as a team leader was listed as a 3.0. Under the category of Ability to Communicate Effectively interpersonal skills (verbal, non verbal, and written) which maintain a high professional quality, ability to write a concise business letter, skill in technical report writing, skill in concise expository writing, and ability to write a team based, case study report were all listed over a 3.5. The lowest ranking communication skill was multi-media skills with a 2.5.

Engineering employees and educators are concerned that their students and new employees are lacking the fundamental skills of collaboration and communication. Studies have also shown that students' misconceptions about engineering may lead them to choose a career in another field. Cunningham and Lachapelle (2007) suggested that starting engineering education in the elementary classroom could improve students' attitudes and conceptions of engineers. This implies that the misconceptions students have going into college could be corrected.

I wondered if there was a way that I could incorporate engineering education into my daily schedule without sacrificing the rest of the 4th grade curriculum. I thought that enrichment time would be the perfect time to thoroughly introduce 4th grade students to the engineering design process. This daily 30 minute block would give students time to work in teams and develop projects using their understanding of engineering concepts. The design challenges would allow students to take concepts they have learned in math and science and creatively solve real world problems. It was my hope that exposing the students to engineering early would improve their attitudes towards engineering and strengthen their ability to work collaboratively. I also felt that doing written projects based on their work would improve their written communication skills.

Assumptions

It can be assumed that all of the data collected during the process of my action research was recorded accurately and that the student participants were not coerced into answering a certain way. One assumption I had during the course of this action research was that my students answered the questions based on their individual beliefs and attitudes. It can be assumed that my own views on the topic of engineering did not influence the interpretation of the data I collected. Another assumption that I made was that all of the students would be present on Mondays, Tuesdays, Thursdays, and Fridays during our enrichment block. This proved not to be the case, as six of my students were absent each Monday due to their required attendance in the gifted program.

Limitations

One of the limitations that I faced was that my action research population was not representative of the 4th grade school population. Due to state laws, students who are identified as having a reading deficiency are required to have focused reading instruction during the iii block. Our school also required that students who did not exceed state reading proficiency standards by a certain percentage must receive reading enrichment during the iii block. A student scoring a level 3 on the state test are considered on grade level. The students who were part of my iii block for this action research study were students who scored high level 3's, level 4's, or level 5's on the 3rd grade reading state test. Another limitation that came about during the second week of my action research, was the change in schedule of six student participants. They were identified as gifted and in order to meet the needs of their individualized education plan (IEP), they were pulled from the enrichment class each Monday. To limit the number of students that were pulled from a single group of 3 to 4 students, I placed only one gifted student in each group. The specially designed groups (iii) were not formed until the third week of school. This made it impossible to administer the pre-test on class climate until after the students had been together for three weeks. I believe my pre-test data on class climate could have been more conclusive had the test been given on the first day of school. The data from the study may have also led to more insight had the study continued throughout the school year. This would have demonstrated the long-term effects that introducing engineering design challenges had on students.

In the following section definitions pertinent to this study were presented.

Definitions

Attitude- personal position that a student holds with regards to engineering

Collaboration - the act of working with another or others on a joint project

Communication Skills – the ability to communicate ones thoughts in a clear and understood manner, either through speaking or writing

Constructivist Learning - a philosophy that states children can learn by constructing their own meaning.

Engineering - designing under constraint to week solutions for societal problems and needs, aiming to produce the best solution given resources and constraints (Cunningham, 2006).

Engineering Design Challenges - using the steps of the engineering design process, students design, create, and improve solutions to an engineering problem (Cunningham, 2006).

Engineering Design Process - a series of steps that engineers use to guide them as they solve problems (Cunningham, 2006).

iii - specifically designed and customized instruction for homogeneous small group or one-on-one reading instruction (FCRR, 2009).

P.O.E.T.R.Y. - rubric that assesses students writing proficiency in the following areas: predict, observe, explain, think, reflect, yearn.

Rubric - describe levels of performance or understanding for a particular topic

Technology – almost anything made by humans to solve a need or fulfill a want/desire (Cunningham, 2006).

Summary

I have explained how my own experiences led me to choose an action research topic on the effects of implementing engineering design challenges during the 4th grade enrichment block. I have stated the purpose for my action research and the questions that guided my research. Chapter one also included the rationale and significance of completing this study and provided definitions of terms that were relevant to the research.

Chapter two reviewed the literature I read related to engineering design process, engineering education in the elementary classroom, writing and communication skills engineering majors lack, collaboration and classroom climate, and writing in the science classroom. In chapter three, I discussed the methodology and design of my action research project. Chapter four included all of the data that I collected, reviewed, and analyzed as it related to the impact that engineering design challenges had on students' attitudes towards engineering and technology, the classroom climate with regards to collaboration, and students' written communication abilities. Chapter five was where I stated my conclusions for this project and examined possible implications of my findings and suggestions for further study on the topic.

CHAPTER TWO: LITERATURE REVIEW

Introducing engineering education at the elementary level is challenging because the school curriculum is already full, and elementary teachers often voice discomfort with teaching science and math (Cunningham, 2007). Everyday students are surrounded by work that was created by engineers, yet they generally don't understand what engineers do (Davis & Gibbons, 2002; Frehill, 1997).

Chapter two examined the engineering design process and students' attitudes towards engineering and engineers. The importance of communication and collaboration with relation to science and engineering was examined and the rationale for and assessment of science reflections was discussed, along with the use of guiding questions in the science classroom.

Engineering Design Process

For the purpose of this action research project the engineering design process is based on the process presented by the Museum of Boston's Engineering is Elementary Curriculum. Several versions of the engineering design process exist. The Engineering is Elementary model is focused on the learning needs of elementary age children and thus depicts fewer steps than some models and uses terminology that children can understand.

The engineering design process is presented as a cycle that can be started at any step. The steps presented in this model are Ask, Imagine, Plan, Create, and Improve. A student working on the ask step could be asking themselves what is the problem, what have others done to solve this problem, and what constraints or limits do I have? During the imagine step students would brainstorm as a class or a group some possible solutions to the problems. They may discuss what they have seen in the real world to solve this problem. For the plan stage students are required to draw a diagram of their proposed technology and make a list of materials they will need. In the create stage students are asked to follow their plan to create a prototype of their technology and to test it. The improve stage involves students talking about what worked, what didn't work, and what might work better. It is during this portion of the design process that students are given an opportunity to modify their design to make it better and re-test it.

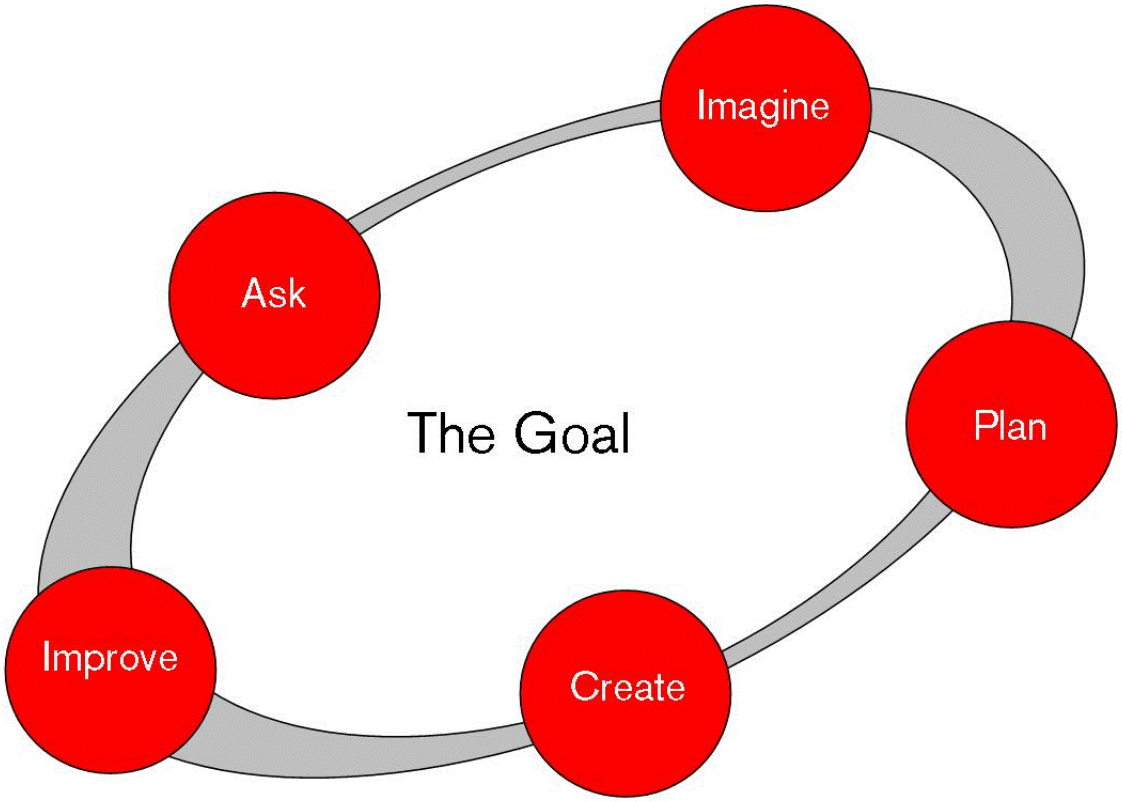

Figure 1 Engineering Design Process Cycle

The Engineering is Elementary curriculum classifies engineering as design under constraint where members of a team seek solutions for societal problems and needs. The aim of engineering is to produce the best possible solution given resources and constraints. Cunningham and Lachapelle (2007) state that at the heart of engineering is an understanding of the engineering design process.

The engineering design process encourages students to communicate their ideas through a variety of methods-verbal, writing, drawing, and building. The way Engineering is Elementary developed this particular engineering design process encourages teamwork and communication as students will need to work together to design and create a solution to a given problem. Cunningham and Lachapelle (2007) states that engineering design challenges that follow the steps of the engineering design process allow students with varying academic abilities to succeed because they are easily scaled to meet the needs of gifted of special education students.

Students' Attitudes Towards Engineering

Engineering is not a subject that is normally taught in the elementary school setting. Studies have shown that elementary students are often unaware of the work of engineers. As our society becomes more dependent on engineering, it is more important than ever that everyone has basic understanding of what engineers do (Cunningham & Lachapelle , 2007). Oware, Capobianco, and Diefes-Dux (2007) showed that students associated engineers with building things and had the misconception that engineers were physical laborers. Cunningham (2010) reiterated the fact that students perceived engineering as a career that involved fixing, building, and driving vehicles. This misconception showed up again in the 2011 study by Capobianco, Diefes-Dux, Mena and Weller.

Cunningham and Lachapelle (2010) found that students who were exposed to an engineering curriculum in elementary school showed more interest in wanting to pursue engineering as a career. Her study used an instrument that measured students' attitudes and perceptions of engineering. The survey was given to students both before and after they were exposed to an engineering curriculum designed for elementary students. The participants were

1,056 students from six different states. The majority of the surveys were competed by fourth and fifth grade students. The time period that elapsed between the pre and post test was between five and seven months. Students who had been exposed to the engineering curriculum were significantly more likely to agree that scientists and engineers help to make people's lives better, and agreed more strongly on the post survey that they knew what scientists and engineers do for their jobs (Cunningham & Lachapelle, 2010). The effect was particularly strong for females and students on free and reduced lunch. Prior to being exposed to an engineering curriculum, students on free and reduced lunch were more likely to be under the perception that math and science had nothing to do with real life.

In another study, Cunningham and Lachapelle (2005) asked over 6,000 students in Massachusetts to complete the phrase "An engineer is a person who…" These open-ended comments were coded and put into categories. The most commonly cited response was that engineers fix things. When students were more specific than "things" they indicated that the items fixed included buildings, cars, electricity, phones, motors, and technology. The second most commonly cited response was that engineers build things. The third most generated response was that they didn't know what engineers do. Two of the three most commonly cited responses among elementary students classify engineers as people who do physical labor that involves fixing and building things.

According to a 2007 study, students who had been exposed to engineering classes before college showed significant increases as to what engineers actually do, and led to a greater interest in pursuing a career in engineering (Hirsch, Carpinelli, Kimmel, Rockland, and Bloom, 2007). A Technology and Engineering Attitude Scale administered prior to completing a class on engineering, showed that elementary students were prone to believe that engineers help to improve the quality of people's lives. The post test showed a 65% increase after students completed a class on engineering (Cook, 2009).

Jerry Yeargan, 2001 President of Accredidation Board for Engineering and Technology, stated that establishing engineering and technology standards "is not about getting more students into engineering; it is about getting the right students into engineering" (Gorham, 2002). Cook elaborates on this quote by stating that "engineering education can present an often-neglected opportunity of an engineering path to those who are well fit and interested" (Cook, 2009, p. 14). If a student is unaware of what it means to be an engineer then they are not likely to pursue an education in engineering.

Capobianco, Diefes-Dux, Mena, and Weller published a study in 2011 in the Journal of Engineering Education about students' conceptions of engineers and the implications these conceptions had for engineering education. This study was conducted on 296 first through fifth graders from both urban and suburban schools; participants were chosen throughout the Midwestern part of the United States. All of the participating students were given the Draw an Engineer Test and 80 of the students (4 from each class) were then interviewed to clarify and examine critically what students had drawn, and how they represented their conceptions and ideas concerning engineering. Upon analysis, four general conceptions of engineers arose. Conception 1 was that an engineer is a mechanic who fixes engines or drives cars and trucks. Conception 2 was that an engineer is a laborer who fixes, builds, or makes buildings, roads, and other objects. Conception 3 was that an engineer is a technician who fixes electronics and computers. Conception 4 was that an engineer is someone who designs. Only a limited number of fourth and fifth grade students (17 %) characterized engineers as designers (Capobianco, Diefes-Dux, Mena, and Weller, 2011). Across every grade level, the great number of students (over 40%) drew Conception 1, representing an engineer as someone who is a mechanic who fixes engines or drives cars and trucks.

Oware (2008) examined nine third through fifth grade gifted students perceptions of what engineers do. These gifted students had already enrolled in an engineering outreach course, so they already had shown some interest in learning about engineering. Prior to taking the class 8 of the students classified engineering work as a physical other than building, and 3 of them classified engineering work as non-physical and related to solving problems. After the class, six students classified engineering work as physical and six students classified the work as nonphysical and related to solving problems.

When students have continued misconceptions about the nature of engineering their desire to want to pursue an engineering career cannot be held as accurate. The false belief that engineers are physical laborers and mechanics could lead students to pursue majors and careers that are not in the engineering field. Eurodice (2002) states that the trends in the rate of graduation in engineering and the physical science have stayed flat or declined, but the demand has expanded. The National Academies of Engineering (2005) presented that they fear students are discouraged from becoming engineers because they fear there is too much work, or lack knowledge about the true nature of engineering. Several engineering fields are not well-known and the opportunities available are not understood (National Academies of Engineering, 2004).

Capobianco et. al (2011) concluded that, based on current research of elementary students' conceptions of engineers, the following attributes need to be associated with engineers in order to inform and to enhance elementary school students' conceptualization of engineers. "An engineer is someone who is creative, uses science, uses mathematics, uses technology, works in teams, designs everything around us, and solves problems to help people" (Capobianco et. al, 2011).

Engineering and Collaboration

A common theme in the upper elementary, middle, and high school classroom is the emphasis on individual activities that do not involve a lot of communication among the students. Palumbo (2006) claims that this emphasis on individual effort and not on group effort is to help students be ready for the work force. He states that companies want employees who are able to think independently and to work without constant guidance. This has led to the problem stated earlier that engineers entering the work force have trouble working in teams and collaborating with others. Due to this lack of practice in collaborating with teams, engineers often enter the work force unable to cooperate and interact with others on their teams.

For student group and team work to be effective, students need to be able to work collaboratively in their groups, and teachers need to find out how their students perceive one another while working in their groups (Quek Choon Lang, Wong Foong Lin 2002). The degree to which competitiveness, friction and cohesiveness are present in the classroom can be measured with class surveys.

Engineering and Communication

Math and writing are natural parts of engineering coursework. In general, writing is not generally considered a natural component of engineering. Northwestern University is working on joining the University's Writing Program with the freshman engineering courses. This partnership was started with the intention of improving the engineering students' communication skills. Students studied the design process alongside communication. As students developed projects they were guided and instructed in three types of communication: oral, written, and graphical. (Hirsch & Shwom,2001). Faculty from both departments, engineering and communication, graded and responded to papers written by the students.

This model served as an excellent rationale for why engineering and science should be taught embedded with writing skills. Riemer states that the Dean of Duke University said that there is ample evidence that graduate engineers lack the standard of communication skills, and "engineers who are adept at communications have a considerable advantage over those who are not" (2002). To benefit students' communication ability, the introduction of writing into the science and engineering curriculum must be explicit. In the course of my action research students responded to teacher given prompts in a science and engineering journal. These reflections were scored and discussed with the students after each challenge with the intent of improving their written communication skills.

Rationale for Science Reflections

Klentschy (2005) suggests that the act of writing can be used to enhance thinking by having the students organize language. When paired with the six components of science (question/problem/purpose, prediction, planning, observations/claims/evidence/what have you learned, new questions) students can take meaning away from the completed engineering activities completed. Mesa (2008) researched a rubric for science that would measure all six of these essential components to science writing. The use of this tool would allow teachers to see if their students were including all the important components of scientific thinking in their written communication.

Science reflections can also be used to facilitate science students' curiosity and engagement in laboratory work (Towndrow, Ling, & Venthan, 2008). Towndrow et. al (2008) suggests another important aspect of science writing is that science should not be about remembering facts and regurgitating information, but about learning to be scientists. Keeping reflections on their experiences and learning help students develop skills, attitudes, and knowledge of how scientists do science. These writing skills can benefit students as they enter the workforce. Reflections provide a great communication tool between teachers and students. Student reflections allow teachers to fully understand the depth of student understanding of materials, the students' thinking processes, and it also allows teachers to address questions that come up that may have otherwise not been asked.

McDonald (2009) states that only using science writing simply as a time to record data and observations does not allow students to do any of their own thinking or explore the learning process. The addition of reflections helps students to take meaning from the learning experience. The reflection can also provide for instant feedback to the teacher as to students' understanding and misconceptions on the lesson just taught. Reflections can be very structured and guided by the teacher or can be open ended and guided by student questions (McDonald, 2009). Reflective thinking and writing is a part of the critical-thinking process that refers specifically to the process of analyzing and making judgments about what has happened (McDonald, 2009). Reflections on group work is conducive to collecting qualitative data about the process of working collaboratively.

Reflective writing allows students to self-examine their learning experience and leads to the development of better critical thinking skills (McDonald, 2009). He also states that deliberate and guided reflection better leads to expanded learning and understanding.

Assessment of Science Reflections

Sadler (1989) explains that "few physical, intellectual, or social skills can be acquired satisfactorily simply through being told about them. Most skills require practice in a supportive environment which incorporates feedback loops. This usually includes a teacher who knows which skills are to be learned, and who can recognize and describe a fine performance, demonstrate a fine performance, and indicate how a poor performance can be improved). Scientific writing, such as would be required by future engineers, is one of these skills that needs to be practiced. Informal formative assessment can be carried out by a teacher as she evaluates students' responses during a class discussion and modifies instruction accordingly. Informal assessment can also be performed by a teacher as she circulates among groups during a lab activity to note what students are doing or as she listens to group conversations to diagnose misconceptions.

Luis-Primo and Furtak (2008) found that 'predict, observe, explain' prompts produced longer, more detailed answers than did graphs. Therefore, the authors recommended prompts with few constraints to gain the greatest picture of student understanding. Interestingly, Luis-Primo and Furtak also found that students' written answers to prompts varied more widely in quantity and quality of thought than did their oral answers. The 'predict, observe, explain' prompts are the foundation of Mesa's P.O.E.T.R.Y. rubric which was used for scoring in this study. The P.O.E.T.R.Y. model expands on the predict, observe, explain prompts by adding sections for reflection and yearn to learn more.

Guided questions in science reflections

According to the National Science Education Standards (NRC, 1996) doing science inquiry includes identifying and asking questions, designing and conducting experiments, analyzing data and evidence, using models and explanations, and communicating findings. To facilitate science students' engagement in science and to ignite their curiosity in the subject, writing can be used as a tool and a student-created learning resource. Towndrow et. al, (2007) stated that there is a need for teachers to guide their students in writing their reflections. They found that if teachers facilitate students in formulating questions about their laboratory learning in writing, it can improve discourse between students and teacher. When students' are properly guided and instructors respond appropriately to reflections, journal writing can be a foundation for a less intimidating questioning culture in science laboratory learning. Communicating via writing is a skill engineers need as they communicate in reports, e-mails, business letters, and proposals.

Reflective writing during an engineering course can be a successful strategy to expose student misconceptions and strengthen their understanding of the content; however, teachers must provide guided question stems to allow students to be successful

Many teachers are familiar with higher order thinking and can incorporate these question stems into their instruction or when framing questions for students. The use of objective questions that require students to conduct research or use critical thinking skills can provide educators with an insight into student thought and learning. One way to gain this feedback would be to use reflection journals; the most common of these journals is a guided reflection paper. As students reflect through guided questions they can begin to pose their own questions for reflection. Some suggested prompts may include: " What is something I discovered for the first time?", "What did I find that was surprising to me?", "What happened reminds me of…" , "I also want to know…" , "Now I wonder…", "I had trouble with…", "I was successful when…" (McDonald, 2009). Student explanations can provide insight into student understanding of content and process. The guided questions students used in this action research related to the use of the engineering design process.

Writing in the Science Classroom

McDonald and Dominguez (2009) suggested that writing in the science classroom successfully develops students' critical thinking skills. These written reflections will serve to provide teachers with insight into students' thinking, attitudes, and learning about the nature of engineering and the content being addressed. The authors also proposed that journaling in the science, or engineering, classroom is a way that students will be able to connect personally with their learning.

Baket et. al. (2008) present supporting evidence not only to McDonald and Dominguez's (2009) findings that writing promotes critical-thinking skills but they additionally provide substantial support that writing also promotes construction of vital scientific concepts and challenges ingrained misconceptions. The goal of writing in science is to improve these skills by helping students to develop them through practice and reflection. The authors encourage teachers to view writing as an integral part of "doing science" (Baker et. al., 2008). As students continually write about engineering, the teacher should be able to demonstrate if the students' misconceptions and ideas about engineers and engineering changed throughout the course.

Personal connection to writing and learning are themes supported by both McDonald and Dominguez (2009) as well as by Towndrow et. al. (2007). The use of reflective writing in the science classroom allows students to connect to their learning by expressing their suspicions, frustrations, and curiosities about the presented concept and even engineering itself. The authors suggest that students' writing as an important tool for teachers to utilize in ensuring clear and accurate student understanding of concepts explored in the science classroom (Towndrow et. al., 2008).

Summary

The science classroom is an appropriate place to have students practice the art of reflective writing. Reflective writing, with the use of guided questions, has shown to provide insight to teachers on misconceptions their students have on presented topics. Using written reflections during a 30 minute engineering class in a 4th grade classroom allowed me to analyze my students' conceptions of engineers and engineering. These reflections, and my own observations, allowed me to observe a change in how my students perceived engineers and engineering.

In chapter three, I discussed the methodology and design of my action research project. Chapter four included all of the data that I collected, reviewed, and analyzed as it related to the impact that engineering design challenges had on students' attitudes towards engineering and technology, the classroom climate with regards to collaboration, and students' written communication abilities. Chapter five stated my conclusions for this project and examined possible implications of my findings and suggestions for further study on the topic.

CHAPTER THREE: METHODOLOGY

Introduction

This action research study investigated the impact my practice of implementing engineering design challenges had on twenty-two 4^{th} grade students. More specifically, I focused on the questions:

1. How did my practice of implementing engineering design challenges during a 4^{th} grade enrichment class affect students' attitudes towards engineering and technology?
2. How did my practice of implementing engineering design challenges during a 4^{th} grade enrichment class affect the classroom climate in regards to collaboration?
3. How did my practice of implementing engineering design challenges during a 4^{th} grade enrichment class affect students' written communication skills?

Design of the Study

This study employed an action research design. Action research is defined as a type of research focused on a specific local problem and resulting in an action plan to address the problem (Frankel & Wallen, 2000). This action research was conducted in my 4^{th} grade classroom during the first and second quarters of the 2011-2012 academic school year. The action research was completed during 4^{th} grades designated iii and enrichment block. Using my research questions as a guide, I implemented engineering design challenges to examine the effect my practice had on students' perceptions of engineering, students' communication skills, and students' perceptions of the class environment with regards to collaboration.

In an effort to ensure credibility in my action research project, the data were triangulated through pre and post surveys that measured students' perceptions of the classroom environment and their attitudes towards engineering, student interviews, teacher observation, and a rubric to analyze students' written communication skills.

School Setting

The elementary school where the action research took place was located in a suburban area of Central Florida comprised mostly of middle-income families. The K-5 population is 626 students. The ethnic population was: Caucasian – 38%, Hispanic – 34%, Asian – 10%, African American – 9%, and other 4%. 38% of the population is comprised of English Language Learners and 28% of the population had an exceptional education (ESE) label. Forty percent of the students received free and reduced lunch. The gender make up was 49% male and 51% female.

Participants

The participants in this action research included twenty-two 4^{th} grade students of ages 9 – 10 years old. The participants were chosen to be part of the enrichment class because they scored as proficient in reading on the prior year's statewide reading assessment. Among the twenty-two students were eleven girls and eleven boys. Nine of these students were Caucasian, seven were Hispanic, two were African American, two were Asian, and two were other (one student was Indian and one student was Middle Eastern). Six of these students were classified as gifted and one of the students was labeled as exceptional education due to hearing impairment. These 4^{th} grade students were representative of the school's ethnic and gender make up. Two of the students qualified for, and received, free or reduced lunch based on their family income.

Procedures

The effects of my practice of incorporating engineering design challenges during a 4th grade enrichment block was the basis for this action research. As the teacher and researcher, I had students complete 5 different design challenges from the Engineering is Elementary curriculum over 10 weeks. These challenges occurred during the 4th grade enrichment block, 30 minutes a day, 4 days a week.

Permission was obtained from the IRB, the county, and the school principal to work with students assigned to this enrichment class. Parents were provided with a letter describing all aspects of the study and given assurance as to their children's confidentiality.

I was able to maintain confidentiality of the students throughout the study as I was the only person with access to the data. Students were assigned pseudonyms for the purpose of data collection and reporting purposes. All data were kept in a locked file cabinet in the researcher's classroom. Parent consent forms were sent home during the first week of school. A phone call or e-mail was done as a follow up to students who did not return the forms within one week. Students were read a student assent script and asked to agree to participate in this study by providing the researcher with their signature. Data of students who did not return the required letters of consent from their parents, or who chose not to complete the letter of assent, were excluded in the final analysis of this study.

Implementation of the Engineering Design Challenges

The first two days of iii, the class during which this action research was completed, were dedicated to administering the pre-test of the engineering attitude survey and the My Class Inventory survey. The first day of class I administered the My Class Inventory survey. I read each question aloud and had students signal they were finished answering the question by placing their pencil down. The students were instructed to answer honestly and told that their answers would not affect their grade or ability to participate in class.

The second day of class I administered the Engineering Attitude Survey. The likert scale was explained by telling the student that if they highly disagreed with the statement they should choose 1, if they somewhat disagreed with the statement they should choose 2, if they didn't have an opinion they should choose 3, if they somewhat agreed with the statement they should choose a level 4, and if they strongly agreed with the statement they should choose a level 5. This clarification was repeated for each question. When the students were ready to complete the written portion of the survey by completing the sentence stem "An engineer is…", I directed them to finish the statement to the best of their ability.

On the third day of class, I introduced students to the engineering design process. Students were given a handout that included the cyclical model of the engineering design process. For each step I explained to the students what they would be doing. The students were told that they would be starting with the Ask task.

The class held a discussion about what kinds of windmills they have seen in person, in pictures, or on television (see appendix L for a brief description of each design challenge). The students wanted to know if they could look up pictures of windmills on the internet. I agreed that this would be an excellent idea and we moved into the computer lab. The students wanted to know what materials they would be allowed to use for the challenge. This was one of the constraints that was placed on them. The student groups had discussions about what materials they thought would be light enough to spin, and what materials would be best to make frames for the blades with.

On the second day, I divided the students up into six groups. Four of the groups consisted of four students and two of the groups consisted of three students. The groups were told they needed to come up with one blueprint for windmill blades. The blueprint had to include a sketch of the blades that indicated the shape, size, and number of blades. The blueprint also had to include a complete list of materials that they would need. The groups were told that they would not be able to ask for additional materials once they had submitted the group's plan and received their materials.

It took two days of building for all six groups to finish their initial prototypes. During the second day of building, one group of four was missing three students, another group of three was missing two students, and a third group of four was missing one student. I realized at this time that every Monday six of my students who were classified as gifted would be absent from class. I directed the groups with the missing students continue to work even though they had several members absent. The absent members returned the next day and met with their groups to be caught up on what they had missed. Once the students had all finished building, we tested the windmills by attaching the blades and Styrofoam ball to the dowel that went through the milk carton. On the side of the milk carton opposite the blades I attached a Dixie cup with a load of 10 pennies and attached it by a string. The base and the blades were set eight inches from the end of the table with the blades facing the edge of the table. A blow dryer was aimed directly at the blades on high speed.

During the next class meeting, the students were instructed to redesign their windmill blades. Each group would again have to come up with a blueprint including a list of all materials they would need. During the redesign, it only took one day for all six groups to finish their blueprints and one day for them to rebuild them.

When class started the next day, the students wanted to know if they would be getting their next design challenge. I reminded the class that they would need to finish up the reflections they had started before they had started designing. The guiding questions the students answered were:

What did you observe when we tested the designs?

Did you consider your initial design a success? Why or why not?

What did you change in your re-design and why? Did these changes improve your design?

What would you do differently if we were to do this design challenge again?

What was the best and worst part about working in a group?

I intentionally did not give the students any guidance on how I wanted them to answer the questions. Several students asked me how many sentences they needed to write for each question. I told them they needed to answer the question but that there was no limit to how many sentences they were required to write.

For the second design challenge, building a water filter, students were placed into new groups. I took care to make sure that there was only one gifted student in each group to minimize the number of students per group that were out on Mondays. The groups were presented with a clear container filled with polluted and discolored water and given the challenge to design a device to design a piece of technology to clean the polluted water. They had to use only the materials that I had made available for them and were required to submit a blueprint prior to obtaining any materials.

After testing their completed filters, the students redesigned water filters they were once again assigned to answer the guiding questions for writing a reflection.

During the third design challenge, designing a hand held pollinator, the students were again put into new groups, with one gifted member assigned to each group. The class was given a lesson on pollination to be sure they understood the concept and purpose of a hand held pollinator. For this design challenge, the students had to design a piece of technology that could be held in the hand and transfer a large amount of pollen evenly onto a poppy style flower. The students were also given the constraint that they needed to create this pollinator as cheaply as they could. The students were provided with a price list for their materials and required to submit one blueprint per group that had a sketch of the proposed pollinator as well as a material and price list. They were not given materials until the blueprints were approved by all members of the team and given to the teacher.

The students fourth design challenge was to design a shock absorbing landing system for a moon lander., For this design challenge, the students did not have to come up with an initial blueprint in order to get supplies. Instead, they were provided with the limited supplies they were allowed to use and told to make a shock absorbing landing system using only the given materials. They produced a diagram of their model as they were building. The students were also given the criteria that the landers would be tested by dropping on to the table top from a distance of 12 inches and that a successful landing would not have the large marshmallow astronauts bounce or fall out of the landed.

The last design challenge this group of students participated in was to design a marble roller coaster. They were given a set time limit to build a roller coaster that would earn the highest number of points. Points were given for how high the roller coaster was, if a marble stayed on track, if a marble landed on a target, and for how many right angles were included in the design.

The main constraints in this design challenge were the limited materials and the limited amount of time the group would get to build their finished coaster. It was discussed with the class that when engineers are hired by companies they must work to meet the needs of the company. Companies, such as amusement parks, will often have a limited budget for a project and a timeline by which the project will need to be completed. Engineers who want to continue to be hired will need to show that they can meet these demands. I had yet to place a time limit on the groups and was worried that they would be nervous. I was quite surprised to see them get excited by the thought of having to finish in a set amount of time.

After the students had finished writing their final reflection I collected their notebooks. I distributed the My Class Inventory instrument and administered it the same way I had on day one of the class. The participants had each item read aloud to them and they were instructed to answer as honestly as possible. I reminded them that their answers should reflect their personal feelings and would not affect their grade or continued participation in iii class.

The next day I distributed the Engineering Attitude Survey to the class. The survey was administered in the same manner it was the first time. Once students were finished with the likert scale questions they were prompted to finish the sentence “An engineer is…”

Instruments

My Class Inventory

My Class Inventory measured five dimensions of social climate and is suitable for children in the eight to twelve year old range. The purpose of the instrument was to determine how children perceived the classroom climate with regards to cohesiveness, friction, difficulty, satisfaction, and competitiveness. It has been extensively field tested, used widely in research, and shown to be reliable. My Class Inventory contains 38 questions that measure five elements of the class: cohesiveness, friction, difficulty, satisfaction, and competitiveness (Anderson, Frasier, Walbert, 1982). Reliability estimates are based on a large and representative sample of 2,305 seventh grade students in 100 classrooms and 30 schools throughout Tasmania, Australia. The cohesiveness section alpha reliability is .80. The friction element alpha reliability is .75. The difficulty alpha reliability is .73. The satisfaction alpha reliability is .88, and the competitiveness alpha reliability is .81. According to Cronbach's alpha an internal consistency rating of between .7 and .8 is considered acceptable, and an internal consistency rating of between .8 and .9 is considered good. Since I used the My Class Inventory to measure collaboration, the two sections of competitiveness and cohesiveness were most important. Both of these elements have good consistency ratings. Anderson, Frasier, and Walbert (1982) feel that classroom climate criteria have not been used nearly as much as they might have when evaluating education innovations, new curricula, and particular teaching approaches.

POETRY rubric

The POETRY rubric was created by Jennifer Mesa and Michelle Klosterman. The acronym POETRY stands for predict, observe, explain, think, reflect and yearn to learn more

(Mesa, 2008). The rubric was used to evaluate students' written reflections after each engineering design challenge. Mesa adapted the POETRY rubric from White and Gunstone's POE (predict, observe, explain) method that focuses on science processes. The additional aspect of think, reflect, and yearn to learn were added so that higher-order processes and scientific habits of mind could be assessed as well (2008).

Each aspect of the POETRY rubric is scored separately as advanced, proficient, basic, or developing with advanced being the highest level of performance and developing being the lowest. Mesa, Klosterman, and Cronin-Jones (2008) determined that this rubric has content-related evidence of validity. The rubric is available in three different formats (traditional rubric, wholeistic rubric, and a checklist). For this study the traditional rubric was used. The wording of each rubric and the criterion for different levels of mastery are all identical in each format.

Engineering Attitude Survey

The Engineering Attitude Survey was originally developed as an assessment of middle school students' knowledge of engineering and their attitudes towards it. Christine Cunningham adapted this survey for use in her study about engineering in the elementary school. Responses were changed form yes/no/I don't know to a 5 point Likert scale. 0 correlated with strongly disagree and 4 correlated with strongly agree. This revised engineering attitudes survey has twenty statements, in which students are asked to indicate their agreement/disagreement to given statements on the five-point Likert scale (Cunningham, 2010). Reliability analysis showed that this was a highly reliable instrument. The twenty questions can be classified as one of three sections; jobs, real life, and cause problems. Reliability analysis of the jobs scale had an alpha coefficient of .833. The real life questions had an alpha coefficient of .729, and the cause problems questions had a Chronbach's alpha coefficient of .715.

Table 1 Engineering Attitude Survey: Survey Questions

Scale	**Number of Questions**	**Text of Component Questions**
Real Life	2	Science has nothing to do with real life. Math has nothing to do with real life.
Cause Problems	2	Scientists cause problems in the world. Engineers cause problems in the world.
Future Engineering Course	1	I would like to take a class in the future about engineering.
Invent	3	I would like a job where I could invent things. I would like to help plan bridges, skyscrapers, and tunnels. I would like a job that lets me design cars.
Help Society	3	I would like to build and test machines that could help people walk. I would enjoy a job helping to make new medicines. I would enjoy a job helping to protect the environment.
Figure Things Out	4	I would like a job that lets me figure out how things work. I like thinking of new and better ways of doing things. I like knowing how things work. I am good at putting things together.
Make Lives Better	2	Scientists help make people's lives better. Engineers help make people's lives better.
Know About Jobs	2	I think I know what scientists do for their jobs. I think I know what engineers do for their jobs.
Scientist	1	I would enjoy being a scientists when I grow up.
Engineer	1	I would enjoy being an engineer when I grow up.

Methods of Data Collection

On the first day of enrichment class students were given the Engineering Attitude Survey. This was done prior to them being told what they would be doing for the enrichment class or receiving any instruction on the engineering design process. On the second day of class students were given the My Class Inventory. This was done before the students had completed any group or team activities. Since students were pulled from several fourth grade classrooms, this particular group of students had not yet functioned as a group. After completion of each design challenge students were given a series of teacher generated prompts to guide them in writing a reflection. The reflections were collected and scored with the POETRY rubric. Upon completion of the five design challenges students were once again given the Engineering Attitude Survey and the My Class Inventory. These two surveys were given on separate days.

Methods of Data Analysis

In this action research study, I used questionnaires, surveys, rubrics, student interviews, and teacher observation to collect data. To measure students' attitudes towards engineering I used a survey, student interviews, and teacher observation. Students were given the engineering attitude survey at the start and finish of the action research project. The pre and post survey results for each question were averaged and compared using a t-test. Questions that showed a statistically significant change between the pre and post test were examined and discussed. Students' classifications of an engineer were recorded before and after the study. The classifications were grouped into categories and the results compared. Results were examined for misconceptions of what an engineer was and attributes that students applied to engineers. Students' classifications were compared to the research done by Cunningham (2007) where students tended to perceive engineers as physical laborers who worked with cars prior to being exposed to an engineering study. The number of students who held these misconceptions were compared to the number of students who perceived engineers as problem solvers who did mental work. The pre and post classifications were analyzed for differences with respects to the number of students who had misconceptions of engineers and the characteristics students associated with engineers. The students were also observed while working on the engineering design challenges and notes were taken if students were having discussions or writing reflections that dealt with their classification of engineers or engineering. These observations were used to confirm the data that students provided in the engineering attitude survey and in their description of an engineer.

To measure students' perception of the class climate I used surveys, interviews, and teacher observations. Students' data from the My Class Inventory instrument were averaged and charted for each element. The pre and post -test averages were compared and analyzed to determine if completing the engineering design challenges in teams affected the students' perception of the classroom climate. Students were also interviewed and prompted to reflect upon the benefits and drawbacks to working in groups on engineering design challenges. Student responses were compared over time to see if perceptions of collaboration changed. Students were observed working in teams with regards to how equal participation was and how students interacted within their own team and with other teams. The data were used to corroborate the results of the student reflections and surveys.

To measure students writing ability all writing samples came from the students engineering journals. Students were prompted to write prior to the initial design and after the redesign of each engineering design challenge. Students were provided with prompts to guide their writing. The prompts included categories that related directly to their experience with the engineering design challenge, and to their thoughts on working collaboratively. All writing was done in the classroom during a 30 minute time block. Students who did not finish their writing were given extra time during our next class meeting. No writing was done outside of the classroom as to limit input from other teachers, siblings, or parents. The writing was then scored with the POETRY rubric, and each of the six domains (predict, observe, explain, think, reflect, yearn to learn more) was scored on a five point scale. The average class score of each domain was recorded. The first and last writing reflection averages were compared to see if students' average scores increased or decreased in each category. Students were also observed to see if they used their reflections during the challenges, if they discussed their reflections with their class, and what their attitudes were toward being asked to write.

Triangulation occurred through different data sources such as questionnaires, surveys, rubrics, interviews and observation. Both qualitative and quantitative data were used to validate conclusions made.

Summary

This action research examined my practice in the implementation of engineering design challenges on 4th grade students' perceptions of engineers, written communication skills, and classroom environment with regards to collaboration. Students were given pre and post surveys and questionnaires and asked to write a reflection at the end of each design challenge. Students participated in five design challenges over the course of ten weeks.

Chapter 4 discussed data collected on 4^{th} grade students' responses to the implementation of engineering design challenges during their enrichment block with regards to their perceptions of engineering, written communication skills, and classroom environment with regards to collaboration. Chapter five stated my conclusions for this project and examined possible implications of my findings and suggestions for further study on the topic.

CHAPTER FOUR: DATA ANALYSIS

The purpose of this action research study was to investigate the effects of my practice implementing engineering design challenges during a 4^{th} grade enrichment class. Twenty-two 4^{th} grade students participated in this study during the fall of 2011. Within the descriptions of each method of gathering and analyzing data the researcher explained what themes emerged. The following questions were the grounds for this action research project.

1. How did my practice of implementing engineering design challenges during a 4^{th} grade enrichment class affect students' attitudes towards engineering and technology?
2. How did my practice of implementing engineering design challenges during a 4^{th} grade enrichment class affect the classroom climate in regards to collaboration?
3. How did my practice of implementing engineering design challenges during a 4^{th} grade enrichment class affect students' written communication skills?

Data

The first question that was investigated in this study was how did my practice of implementing engineering design challenges during a 4^{th} grade enrichment class affect students' attitudes towards engineering and technology. To determine students' attitudes towards engineering, an engineering attitude survey was administered prior to starting the engineering design challenges.

Research Question 1: How did my practice of implementing engineering design challenges during a 4^{th} grade enrichment class affect students' attitudes towards engineering and technology?

To answer research question one students completed an engineering attitude survey prior to and after completing five engineering design challenges over the course of ten weeks. As students were working I observed students as they worked in groups and discussed what engineers did for a living. Students were also instructed to answer an open ended prompt that stated “An engineer is…” prior to and after completing the design challenges.

Table 2 indicated students' pre and post responses to the Engineering Attitude Survey.

Table 2 Engineering Attitude Survey Pre-Post Means

Scale	**Number of Questions**	**Pre Test Mean**	**Post Test Mean**	**Sig.**	**Text of Component Questions**
Real Life	2	1.3	1.4	.129	Science has nothing to do with real life.
					Math has nothing to do with real life.
Cause Problems	2	3.3	3.6	.104	Scientists cause problems in the world.
		2.1	2.2	.515	Engineers cause problems in the world.
Future Engineering Course	1	2.7	3.5	.047*	I would like to take a class in the future about engineering.
Invent	3			.043*	I would like a job where I could invent things.
		2.6	2.75	.547	I would like to help plan bridges, skyscrapers, and tunnels.
		3.3	3.8	.086	I would like a job that lets me design cars.

Scale	Number of Questions	Pre Test Mean	Post Test Mean	Sig.	Text of Component Questions
Help Society	3	2.8	3.1	.785	I would like to build and test machines that could help people walk.
		2.6	2.7	.840	I would enjoy a job helping to make new medicines.
		3.6	3.9	.011*	I would enjoy a job helping to protect the environment.
Figure Things Out	4	3.4	3.7	.231	I would like a job that lets me figure out how things work.
		3.8	4.0	.276	I like thinking of new and better ways of doing things.
		3.4	4.0	.025*	I like knowing how things work.
		3.3	3.6	.574	I am good at putting things together.
Make Lives Better	2	3.9	4.3	.790	Scientists help make people's lives better.
		3.9	4.1	.280	Engineers help make people's lives better
Know About Jobs	2		4.1	.003*	I think I know what scientists do for their jobs.
		3	4.1	.012*	I think I know what engineers do for their jobs.
Scientist	1	3.1	3.45	.045*	I would enjoy being a scientists when I grow up.
Engineer	1	3.05	3.54	.017*	I would enjoy being an engineer when I grow

Scale	Number of Questions	Pre Test Mean	Post Test Mean	Sig.	Text of Component Questions
					up.

*item found to be statistically significant

The results of the pre and posttest were compared using a paired t test. A question was considered to have significant results if the significance value was less than .05. The mean and significance value of each question on the survey were listed in the table.

The data results were consistent with previous studies done on this topic. The population of 4^{th} grade students that participated in this action research study were significantly more likely to say that they would enjoy being a scientist or an engineer after having completed engineering design challenges. After completing 10 weeks of engineering design challenges, participants in this study were significantly more likely to say that they would be interested in taking a future course in engineering. The students who participated in this action research project were also significantly more likely to say that they thought they knew what engineers and scientists do for their jobs. This data supported the conclusion that as students are more confident in their knowledge of what engineers do, they are more likely to say they would want to be an engineer or take a future engineering class.

I classified the students' responses to the question "What is an engineer?" into categories. The student responses for this question on the pre-test were shown in table 3.

Table 3 Student Classification of an Engineer Pre-Test

Category	**Number of Students**	**%**
Works with cars (physical)	5	23
Works with trains (physical)	1	5
Builds/fixes things (physical)	10	45
No response	1	5
Works with electronics (physical)	4	18
Designs things (mental)	1	5

Ninety-one per cent of the students who participated in this study associated engineers with physical laborers prior to completing the engineering design challenges. Only 5% of students identified engineers with doing a job that involves mental work. The greatest number of students in my action research study, 45%, classified an engineer as someone who built or fixed things.

During the administering of this test, two students, Jonah and Travis, raised their hand. Travis was concerned that he did not know what an engineer was and would get the question wrong. I explained to the entire class that they would not be marked right or wrong for this answer and that the question existed only to let me know what they already knew about engineers and engineering. Jonah explained to me that he really didn't know what an engineer was and that he didn't want to guess. He decided to leave his answer to that particular section of the survey blank. I spoke to him privately and he confided in me that he had heard of engineers before and knew that they were really smart people and he was not sure he wanted to take a class that had to do with engineering because he was afraid of receiving a poor grade. I clarified to him that the purpose of the class was to learn about the work that engineers do and that there would be no grade associated with the class. Upon hearing that there was no grade assigned to the class, he stated that he would like to learn more about engineers but he didn't want to have to take a test about them. This helped to verify the results of the engineering attitude survey in that students were not familiar with the work that an engineer does.

Teacher Observations

Windmill Design

During the class where students were instructed to redesign their windmill blades, each group would have to come up with a blueprint including a list of all materials they would need. As they were working, I noticed Alejandro was sitting back and not participating. When I asked him and his group why he was not participating his reply was "I don't even know if I'm part of the group. I want to share ideas too, they always take Joseph's ideas just because he's smart." The group then decided that even if they didn't use Alejandro's idea they were going to let him help write the list of materials they would use. I recalled during our initial talks about engineering that Jonah had mentioned that he considered engineers to be very intelligent and that he found this intimidating. The comment Alejandro made, and the decision of Joseph's group to use his ideas because he was gifted, helped to confirm the fact that some students may think that engineering is not suited for them because it is too difficult and only for "smart students."

Water Filter Design

During the ask and imagine processes of the water filter challenge, I realized that most of my students did not have much familiarity with water filters. Conner, one of my gifted students, proudly exclaimed that he had built a water filter during a science camp. He also exclaimed that the one he built in this class would not be as good because he would not have access to charcoal. Skyla told the class that the fish tank in her room had a filter and when she changed it she thought it was filled with some kind of rocks or sand because of the texture but that she wasn't sure because her Mom wouldn't let her cut it open and look inside.

Pollinator Design

During the class ask and imagine discussions for the hand held pollinator challenge, Hunter asked, "Why would we want to try to make a cheap pollinator? Won't it just fall apart? If they spent more money it would be better." Binh explained that maybe the farmer didn't have a lot of money, or maybe he had to buy many of them for all of his workers so he couldn't afford expensive ones. Kimberly contributed to the discussion by suggesting that if they work in a field it's probably easy to drop things and lose them. If the pollinators were cheap it wouldn't matter if they got lost. Hunter was satisfied with these explanations and seemed to understand why money could be a constraint to engineers who are working to meet the needs of certain clients.

Moon Lander Design

For the moon lander shock absorbing system design challenge, students were eager to engage in the ask and imagine discussion sessions. During our science class we had just finished studying the space race. The students were excited to connect what we were doing in science class to what we were designing in iii. Having just seen pictures and videos of The Eagle moon lander, students had a greater understanding of the concept they were going to be designing.

This made me believe that incorporating the design challenges into the science block, as they were intended, would deepen the students understanding of not only engineering, but of the science concepts being presented.

Roller Coaster Design

The main constraints in the roller coaster design challenge were the limited materials and the limited amount of time the group would get to build their finished coaster. It was discussed with the class that when engineers are hired by companies, they must work to meet the needs of the company. Companies, such as amusement parks, will often have a limited budget for a project and a timeline by which the project will need to be completed. Engineers who want to continue to be hired will need to show that they can meet these demands. I had yet to place a time limit on the groups and was worried that they would be nervous. I was quite surprised to see them get excited by the thought of having to finish in a set amount of time.

Reflection

Table 4 shows how the participants in this study responded to the question, “What is an engineer?” on the post test.

Table 4 Student Classification of an Engineer Posttest

Category	**Number of Students**	**Percent**
Works with cars/trains (physical)	0	0
Builds/fixes things (physical)	8	36
Designs, plans, and improves things (mental and physical)	5	23
Works with electronics (physical)	0	0

Category	Number of Students	Percent
Makes lives easier/better and solves problems (mental)	7	32
Solves problems (mental)	2	9

Prior to completing the 10-week course of engineering design challenges, 28% of participating students incorrectly believed that engineers worked with cars and trains. Ninety-one per cent of participants also classified engineering as a physical job. After completing the course, there were 0 students who still believed that engineers worked with cars and trains and only 36% of students wrote a description of an engineer that included only physical work. This shows a decrease in the number of students who held misconceptions about the nature of engineering.

After participating in this action research project, 64% of students classified engineers as doing some kind of mental work. 32% of students altered their definition of an engineer to include the fact that they made people's lives easier and/or better by solving problems. 0% of students included this belief on the pretest. So while the engineering attitude survey did not show any significant difference in students believing that engineers make lives better after having completed the engineering design challenges, their written definitions showed that they consider improving people's lives a key characteristic of an engineer. This characteristic was not present in any of their pre-test descriptions.

Completing the engineering design challenges resulted in my students having a more positive attitude toward engineering. Students in this study had an increased interest in wanting to pursue a career or future course in engineering, a greater confidence in their understanding of what an engineer does for a living, and provided more accurate descriptions of engineers.

Question Two

The second question that was investigated in this study was how did my practice of implementing engineering design challenges during a 4th grade enrichment class affect the classroom climate. To determine how students perceived the classroom climate the students were given the My Class Inventory survey prior to and after completing the five design challenges over the course of ten weeks. As students worked in teams their methods of sharing ideas, collaborating, and approaching problems were observed and recorded. Students answered questions about the benefits and drawbacks of working in a group in their engineering journal.

Research Question 2: How did my practice of implementing engineering design challenges during a 4th grade enrichment class affect students' perceptions of the classroom climate?

Table 5 shows how students responded to the My Class Inventory on the pre-test.

Table 5 My Class Inventory Pre-Test

Name	**Satisfaction**	**Friction**	**Competitiveness**	**Difficulty**	**Cohesiveness**
Lily	11	7	9	5	7
Karina	13	5	11	5	7
Ashley	10	5	11	7	10
Raven	13	5	9	5	11

Essence	13	5	13	5	15
Skyla	7	7	11	5	7
Jonah	7	9	13	5	7
Ryan	15	5	11	5	11
Binh	15	6	5	5	11
Hunter	13	5	5	5	11
Name	**Satisfaction**	**Friction**	**Competitiveness**	**Difficulty**	**Cohesiveness**
Conner	9	7	13	5	7
Mikell	15	5	13	5	13
Christopher	9	7	13	8	9
Eve	15	5	9	7	11
Eibhlin	15	5	9	5	15
Travis	13	7	12	5	9
Bianca	13	7	9	5	9
Marcel	15	7	9	5	15
Nicole	13	8	13	8	8
Kimberly	13	5	5	5	9
Alejandro	15	9	15	5	7
Joseph	9	9	15	5	7
Mean:	12.32	6.36	10.14	5.45	10.09

A score of five is the lowest that any category could receive. A low score indicates that the component being measured is not seen as present. The highest score a category could have received was a 15. A high score would indicate the students felt that the component being measured was seen as prominent in the classroom. According to the survey results, the students gave difficulty the lowest rating. This indicates that the students felt that the course was not going to be difficult. When asked about why they rated the difficulty so low seven students responded that it was going to be easy because they knew they would not be receiving any grades.

The category that received the highest rating was satisfaction. Several students stated that they always enjoyed iii class because they got to do projects that they did not receive grades for. The students seemed very fixated on the fact that they were not going to be graded on the work they were doing in class. Only one student, Hunter, said that he was looking forward to the engineering class because he wanted to be a computer engineer when he grew up. This was also the same student who classified an engineer as someone who designs things on the engineering attitude survey.

Teacher Observations

Windmill Design

On the second day of class, I divided the students up into six groups. Four of the groups consisted of four students and two of the groups consisted of three students. The groups were told they needed to come up with one blueprint for windmill blades. The blueprint had to include a sketch of the blades that indicated the shape, size, and number of blades. The blueprint also had to include a complete list of materials that they would need. The groups were told that they would not be able to ask for additional materials once they had submitted the group's plan and received their materials.

As the groups worked their initial designs, I watched one group try to come to consensus on the number of windmill blades they should use. Marcel shouted at his three group mates "No, I will decide how it is done." The group agreed that one person should not make the decision and they narrowed their choices down to four blades or five. To solve the dispute the group resorted to playing a game of rock, paper, scissors. I chose not to interfere with this group's decision making process as I wanted to see if the way they shared ideas would change over time without input from an adult.

Another group had decided on the size, shape, and number of blades they wanted to build. They had also decided on the materials they would use to construct the blades. Ashley was trying to convince her group that they needed a particular color of felt to cover their cardstock blades. When Eve asked her for clarification on why they even needed felt Ashley's reply was, "We need to make it look better." Eve responded with, "The color of the blades doesn't matter, it just needs to work." Ashley and her group decided not to include felt in their material list.

Eibhlin, Lily, and Binh were all busy drawing their blueprint and deciding on materials. I noticed that their blueprint included more than just the windmill blades, but the windmill base as well. Upon questioning, they explained that they were designing decorations for the base so that their windmill would look the nicest. I clarified to them that they were only to design the windmill blades, they were not decorating the base. They then stated had not even started talking about the blade design yet, but that they would start it now. Once they started discussing the materials to use in their blade construction, Binh mentioned that he thought they should use heavy paper because "that's what pinwheels are made of and they blow really well in the wind." Lily was happy with this suggestion and told him, "that's a good idea." I was impressed that one group was sharing ideas and not simply giving directions as to what should be done.

Of the six windmills tested not one of them had the blades make even one complete rotation. Jonah started to get upset with his group because he believed they were going to get a bad grade. I reminded the class that they do not receive a grade for iii and that not all projects were going to work the first time and that is why we were going to have a class discussion about what we observed prior to doing the redesign. The class discussed reasons that the blades did not work and how they could improve their designs. Eve asked if I could re-angle the blades of one windmill and re-test it just to see what would happen. The rest of the class wanted to see this as well because they believed that the blades were not catching enough wind to be effective. I had Eve come up and reposition the blades to an angle the class agreed upon and re-tested the windmill. The class cheered when the windmill blades spun around 2 complete rotations before becoming misaligned.

While Ryan's group was finishing up their blueprint and explaining it to me so they could receive their materials, Ryan became visibly upset. When I asked him what was wrong he stated, "Lily's group heard our idea and I think they're going to copy it. We shouldn't have said it so loud." Lily then replied, "It wasn't your idea. The whole class talked about how cardstock was less likely to rip during our discussion. I just forgot about it until I heard you mention it. That's not copying." This was evidence that certain groups considered the challenge a competition and that they were not willing to openly share ideas with other groups.

During the redesign, it only took one day for all six groups to finish their blueprints and one day for them to rebuild them. The next day, we tested the new designs and four of the six windmills successfully lifted a load of 10 pennies when blown with a hair dryer from a distance of eight inches. Marcel's group did not have a successful test and he loudly exclaimed to his group, "I told you we should have done it my way. This is what I get for getting outvoted by girls." His group reminded him that he had not been outvoted, that they had used rock, paper, scissors, as he had suggested, and he had lost. Another group stated, "Rock, paper, scissors doesn't seem like a very good way to choose which idea to use. Our group used different pieces of both Ryan and Hunter's ideas based on how they explained them." This lead me to believe that some of the students were already collaborating as a team, while others were still feeling very competitive. I was happy to see that a peer of Marcel's had made the suggestion that rock, paper, scissors might not be an effective strategy for decision making in engineering.

Water filter Design

During the prediction reflection writing of the water filter design challenge, Karina wanted to know if she could write about some of the ideas other people had discussed in class. She said she wasn't sure she could use them because they weren't her ideas. I stopped the class for a discussion about sharing ideas. We discussed the fact that engineers use ideas from several sources and individuals to come up with new solutions to problems. Lily remembered that "The redesign from the windmills was easier than the design because we were able to use what we saw from other groups. It was easier than coming up with the ideas all by ourselves." The class came to agreement that it would be ok to use someone else's idea in their prediction. This was evidence that some students were starting to believe that the sharing of ideas was an acceptable thing in engineering.

As students were building, I observed several different ways the students were working to resolve conflicts they encountered while trying to agree upon a single design for the entire team. I was impressed that Marcel, who during the previous design challenge had told his group that they would do everything his way before finally consenting to settling the dispute with a game of rock, paper, scissors, and Alejandro, who previously had felt left out of his group, were working collaboratively with their third partner. When asked how they agreed on the design that they were drawing Alejandro proudly exclaimed, “We combined two ideas that we had into one. We think that the way I want to cut the bottle is the best, and that the order Marcel wants to put the materials in will work the best. Now we have two good ideas in one.”

Evidence of the concept of sharing and combining ideas was present in another group between Eibhlin, Ryan, and Mikell. Ryan’s group was having difficulty agreeing on an idea. So Ryan suggested, “Why don’t we each draw our idea first, and then talk about them.” After each group member presented their ideas Eibhlin told Ryan “You have a really good idea about the little holes in the bottom of the container, we should combine that with Mikell’s idea about the cotton balls.” When I approached Ryan and Mikell about how they felt about collaborating and putting together ideas Mikell interjected, “It was my idea! I get the credit, you think my idea is good, don’t you?” I let the group know that I was proud of each of them for contributing the overall design of their water filter. While it seems as though the group was working cohesively, Mikell’s outburst suggested that he still wanted individual credit and was displaying signs that he was competing against members of his own group.

While evidence of sharing and compromise were evident in two of the teams, one group was still having difficulties agreeing on a design. Jonah told his group "We will make the holes small, big holes will let the water out too fast and it won't get clean." His group member Karina was trying to explain to him, "You can't just do whatever you want, we have to agree. We are a team. Engineers work in teams, not by themselves, that way they get lots of good ideas together." This was the first time in class that any member of the group had made the connection that that not only do engineers work in teams, they do it so that they can combine several good ideas into one project. Even though Jonah was obviously still upset, he conceded and let the group vote on the size of holes to use in their project.

Pollinator Design

As the groups started working on the handheld pollinator design challenge, I immediately noticed a change in several teams approaches to coming up with one idea. In Bianca's group each member had a piece of paper and each person was drawing their ideas independently. I asked them why they were working alone when they would have to turn in only one blueprint. Bianca explained that they had decided as a group to each record their ideas and then they were going to explain their idea to the whole group so they could see which ideas they liked best. Her group also had out their prediction reflections. I asked Bianca why they had out their reflections and she replied that they were going to read them to each other when they showed their drawings so they could make a better decision. This was the first instance where the students were looking back to their reflection during their planning. Marcel's group had a similar strategy in that each group member was sharing their ideas out loud and each member was writing down the ideas they liked best. They told me the intention was to combine all the ideas they thought would work into one. This was evidence that students were not being as competitive within each group.

Travis and Ashley's group was having difficulty deciding between two ideas that they both thought would work. Travis said to the group, "Why don't we just try one and we know we'll get to redo it during the redesign if it doesn't work." Ashley came back with, "Yes, and we can also use the ideas that worked with the other groups to make the 2nd one better." The groups were vocalizing that it was ok to use another group's idea in their design. They were no longer calling it "stealing ideas." This showed me that the groups were starting to act less competitive towards each other.

Karina and her group were having difficulty in getting Jonah to participate. He was sulking because "the group is not listening to me." Karina called me over and said they were having a difficult time getting Jonah to explain what he thought they should do rather than just saying that they needed to do it. Due to this frustration, Christopher had decided that "I don't want to fight, so I'm just not going to give any ideas or help build." Jonah was very concerned that his idea was not going to get voted on and they would "never know if my idea really works." The group eventually decided to use some of Jonah's ideas but not all of them. Christopher still chose to sit out because he did not want to argue with Jonah. This was evidence that Jonah was still viewing the challenges as a competition. He was also causing friction between his group members.

During the redesign of the handheld pollinators, I noticed that students were starting to recognize that individual students had certain strengths they brought to the group. Eve asked Ashley to bend the pipe cleaner like she did for the initial design because she did such a good job at it before. Travis asked Essence if she could do the drawing of the blueprint because her drawings were more detailed and easier to read. Eve brought up in discussion that she was glad we were working in teams because she wasn't very good at doing the building, but she was good at the planning. This was evidence that the group was becoming cohesive and working together. She vocalized that having lots of different people in her group meant that certain people were better at certain things and she believed that their pollinator came out better due to the fact that they worked as a group. "It wouldn't have come out this nice if I had to do all the building on my own. I hope that when engineers get in teams they have people who are good at certain things." This was the second time that a student had mentioned out loud that they believed there was a benefit to engineers working in groups versus working independently.

Moon Lander Design

When students began working on their fourth design challenge, moon landers, I noticed that for the first time all of the students were working. There were no individual students sitting back observing. For this design challenge, the students did not have to come up with an initial blueprint in order to get supplies. Instead, they were provided with the limited supplies they were allowed to use and told to make a shock absorbing landing system using only the given materials. They produced a diagram of their model as they were building. The students were also given the criteria that the landers would be tested by dropping on to the table top from a distance of 12 inches and that a successful landing would not have the large marshmallow astronauts bounce or fall out of the landed.

Each group was using different strategies to come up with ideas and split the building work. Binh's group of three had divided up the tasks based on their abilities. One person was cutting straws, one person was taping marshmallow pads to the straws, and one person was folding springs out of index cards. I asked how they decided who would do what, and they stated that they were each building the part of the lander that they had thought of. When they finished building their individual pieces, they stated they were going to try to make it all fit on the moon lander so everyone's ideas got used. They were going to watch carefully when it landed to see what helped absorb the impact of the landing the most.

Marcel shouting for my attention interrupted me from talking to Binh's group. His group was each taking turns dropping their lander to test their initial design. Marcel wanted to share with me that "We all agreed on how to build it, and it works!" He was very excited that him, Nicole, Jonah, and Kimberly had all agreed on a single design with no arguments. This was the first design challenge I observed where Jonah did not get into an argument with his group about using only his ideas. This was evidence that he was reflecting on his own behavior within the group. It should be noted that this was also the first design challenge where the students were not required to make a blueprint before they started building. I believe that this may have made it easier for the groups to test out different ideas and come to consensus. Prior to this they had to come up with an idea and agree upon it, this meant that they were not sure if the idea was going to be effective or not. I believe in subsequent design challenges I may ask students to come up with the blueprint as they work, instead of in advance.

Skyla, Ryan, and Travis were adding one component to the lander at a time and then testing it. They explained to me that they each were adding their own piece, testing it, and then deciding if the idea was good or not. The group was very encouraging to each other, even when something was not working and the marshmallow astronauts fell out of their lander. When

Skyla's straw feet fell off when the lander was dropped, the rest of the group provided her with ideas on how to attach them more securely. Ryan saw that Travis was having trouble folding his index card into a spring. Rather than simply take over Ryan took another index card and showed Travis the way that he did it. Travis was then able to complete his part of the build.

Roller Coaster Design

It was encouraging to see the students coming up with ways to incorporate ideas from each group member into their designs. During this fourth design challenge there were no arguments about whose ideas were going to be used in designs or worries that one group was copying another.

Christopher immediately showed that he was ready to participate. A group member who had worked with him on a previous design challenge when he had chosen not to participate asked him why he wanted to help this time. Christopher explained, "Well, if our team wants to meet the time deadline, I need to help. There wasn't a time deadline before."

Alejandro's group was discussing what goals they should have. Alejandro stated, "Our goal should be the most points. Let's have lots of right angles and get all five marbles in the cup. That's worth more points than how high we make the track." He was referencing his prediction reflection as he was talking. He had taken the time to consider that the goal was the most points. Other students in his group had not considered points and wanted to make their roller coaster the tallest and fastest. Once Alejandro explained the reason he wanted to have several right angles, so they could accumulate points, they wanted to go with his idea. I was happy to see that students were now taking time to explain why they thought something should be done. In the first challenges students would just shout out their ideas without an explanation as to why they thought the idea would work. Alejandro's group was then working together to discover a way to ensure the marble would make it all the way down the track, even after going through several right angles. After a few failed attempts the group was able to come up with a track that had 3 right angles and allowed the marble to hit a target each time. The entire group cheered and high fived.

Binh's group was not having success at keeping the marble on the track. Without asking for permission from his group, Binh went over to Alejandro's group after he heard them cheer. He asked them to explain how they got their roller coaster to work. Based on prior events in the class, I anticipated that Alejandro's group would tell him that he was not allowed to look at their design. Instead, the group explained how they had folded the index cards into a U shape to keep the marble from following out. Two other groups saw Binh asking another group for help and immediately raised their hands.

"Are we allowed to get up and look at other groups designs?" Conner's group immediately stated that was cheating, but Alejandro's group stated that they didn't mind sharing how they made their successful roller coaster. Conner still insisted that we should not be able to see other groups' designs until after the first test. I stopped the entire class and asked them their opinion on this matter. The class ended up agreeing that it was a good idea to share what was working because they would end up with more successful roller coasters. Their rationale was that if they shared ideas within their group, there was no reason they shouldn't be able to share with other groups.

Kimberly stated that engineering wasn't like a regular class where you could cheat. "In regular class where we get grades I wouldn't want to share my answer with anyone because the teacher would say I was cheating. Here the teacher says we can share ideas and our projects always turn out better after we see each other's projects. I don't think you can cheat in engineering class." This belief was also found in Palumbo's (1999) study that showed students are reluctant to work collaboratively due to the fact that so much emphasis is placed on individual effort and achievement in the classroom.

Once the class agreed that it would be ok to ask other groups questions during the initial design phase, the students started asking groups that said they had a finished product questions about their design. They wanted to know how many points they thought they would earn and if the marble was making it into the target each time. The groups that asked questions went back to their design and altered it to include some of the elements they had seen in the successful tracks. This was evidence to me that the class was now experiencing much less competition and friction. During the first design challenges, students became visibly upset when another group overheard any of their ideas. For the last design challenges, students were willing to ask other groups to explain their ideas in the middle of the initial design.

Class Inventory Results

Table 6 showed the comparison of the pre and post test results of the My Class Inventory instrument.

Table 6 My Class Inventory Pre Post Means

MCI scale	**Number of Items**	**Pre Test Mean**	**Post Test Mean**	**Sig.**
Satisfaction	5	12.32	13.95	.009*
Friction	5	7.24	6.24	.031*

Competitiveness	5	9.90	9.43	.506
Difficulty	5	5.48	5.57	.743
Cohesiveness	5	10.24	11.19	.089

*item found to be statistically significant

The perceived classroom climate was composed of five different elements: satisfaction, friction, competitiveness, difficulty, and cohesiveness. The pre and post survey data were compared using a paired t test. To demonstrate a significant change in the pre and posttest the significance value must be lower than .05. The pre and posttest means and the resulting significance value are shown in the table below.

The My Class Inventory results did not show a significant change in either competitiveness or cohesiveness among the students who participated in the design challenges. The only areas that showed a significant difference were friction and satisfaction. Students were significantly more satisfied with their iii class after they completed the five engineering design challenges. Students who participated in this action research project also felt that there was less friction, or disagreements, in the class once they had completed the 5 engineering design challenges.

The decrease in the perceived amount of friction in the class was confirmed through my observations as the frequency of disagreements in the groups decreased. Student interviews about the benefits and drawbacks of working in groups also verified these findings. After the first two challenges students responded that the worst part of working in a group was being told what to do by other group members and watching fights between other group members. After the last design challenge only one student still mentioned disadvantages of working in a group. Even then the disadvantage did not mention friction between other group members.

I was surprised to see that the students did not see a significant decrease in competitiveness as observations and student interviews would lead me to believe that students were much less competitive at the end of the ten week course than they were at the start. At the start of the 10 weeks, students did not feel comfortable having other groups look at their designs because they felt the other groups would "steal their ideas." During the last design challenge, at the end of the 10 weeks, the students felt comfortable enough to share their ideas with other groups during the initial design phase.

The observations I made also showed that the students had an increase in the amount of cohesiveness in the classroom. However, this was not confirmed through the use of the My Class Inventory survey. During the first two design challenges, students would argue within their own groups as to which ideas should be incorporated into the group's design. Some groups would resort to games such as rock, paper, scissors to solve disputes. By the end of the 10 weeks groups were all contributing ideas openly and using several group members' ideas to create one piece of technology.

I was surprised to find that the satisfaction level of the class had risen to a degree to be deemed statistically significant. This was surprising to me in the regards that it was the category with the highest rating at the start. I felt that this had to do with the fact that few students were familiar with the term engineer or engineering prior to taking the test the first time. This may have caused some anxiety in them as to what they were going to be asked to do in the class. This could also corroborate the reviewed literature that stated students who did not have a clear understanding of the term engineer were not likely to want to take a course in engineering. When interviewed after the pre tests students stated they were satisfied with the class because there were no grades assigned to it. Upon completion of the engineering design challenges, students stated they were satisfied with the course because they enjoyed completing the engineering design challenges. Students were visibly disappointed to hear that the design challenges would not continue after winter break.

Question Three

The third question that was investigated in this study was how did my practice of implementing engineering design challenges during a 4th grade enrichment class affect students' written communication skills. Students' communication skills were measured through their responses in their engineering journals. The students were prompted to write prior to their initial design and after the redesign for each engineering challenge. Their reflections were rated with the P.O.E.T.R.Y. rubric.

Research Question 3: How did my practice of implementing engineering design challenges during a 4th grade enrichment class affect students' written communication skills?

To answer research question three, students completed written reflections prior to completing their initial design and after the redesign for each engineering challenge. These results were scored using the P.O.E.T.R.Y. rubric. Students were observed in their reactions to being asked to write and in the way they were using their reflections for reference during the design challenges.

On the third day of class, students were introduced to their first engineering design challenge, the designing of windmill blades. After the class discussed what they knew about windmills and what ideas they had, the students were told to write down a prediction as to what they thought was the best approach to this challenge. When the students were told that they would have to write down predictions about what they thought would work best, they expressed displeasure. Alejandro wanted to know, "Why did we just spend so much time talking about it if you were just going to make us write it all down anyway?" Kimberly made the comment, "I thought we were doing engineering, like building things. I didn't think we had to write in this class." To me this was a demonstration that Kimberly had the misconception that engineers only do physical work.

Thirteen out of the twenty-two students wrote less than 3 sentences in order to predict what materials, blade shape, and number of blades would work best. Only 2 of the students elaborated on the reasons they chose certain materials.

The day after we completed the second round of testing for the windmill blades, the students wanted to know if they would be getting their next design challenge. I reminded the class that they would need to finish up the reflections they had started before they had started designing. The class gave audible groans and Conner wanted to know, "Why do we have to write if we're not going to get a grade?" Based on student reactions, the students did not feel like writing down what they learned was an important part of the engineering process.

The guiding questions the students had to answer were:

What did you observe when we tested the designs?

Did you consider your initial design a success? Why or why not?

What did you change in your re-design and why? Did these changes improve your design?

What would you do differently if we were to do this design challenge again?

What was the best and worst part about working in a group?

I intentionally did not give the students any guidance on how I wanted them to answer the questions. Several students asked me how many sentences they needed to write for each question. I told them that they needed to answer each question to the best of their ability. I did not give them a set number of sentences to write.

Table 7 indicated the scores the students received based on their first written reflection.

Table 7 First Written Response Data

Name	Predict	Observe	Explain	Think	Reflect	Yearn
Lily	4	10	6	3	4	3
Karina	7	9	6	3	3	3
Ashley	6	9	8	5	7	4
Raven	9	11	6	6	10	5
Essence	5	6	7	3	6	3
Skyla	4	7	6	3	4	5
Jonah	3	9	8	3	7	3
Ryan	3	4	8	3	6	4
Binh	4	3	5	3	9	3
Hunter	5	6	5	3	8	3
Conner	6	3	8	5	9	7
Mikell	3	5	7	4	6	4
Christopher	3	7	7	3	6	3
Eve	3	5	9	4	7	3

Name	Predict	Observe	Explain	Think	Reflect	Yearn
Lily	4	10	6	3	4	3
Karina	7	9	6	3	3	3
Ashley	6	9	8	5	7	4
Raven	9	11	6	6	10	5
Eibhlin	5	5	3	3	3	3
Travis	5	7	7	3	7	8
Bianca	3	7	6	3	5	3
Marcel	6	7	9	5	5	4
Nicole	4	8	4	8	5	4
Kimberly	4	5	7	4	4	3
Alejandro	3	9	4	4	5	3
Joseph	4	9	5	3	5	4
Mean:	4.5	6.86	6.41	3.82	5.96	3.86

The lowest score that a student could receive for any category was 3, and the highest score they could receive was 12. On average, the students were most successful with the observe and explain components of their writing. The components that the students scored the lowest in were yearn and think.

After I had scored the writing the students had their journals returned to them. I showed them a copy of the rubric and explained to them how they were scored. When asked why they believed that their scores for explain and observe were the areas they received the highest scores in, Lily and Jonah stated that the questions I asked for guiding questions were most related to these questions. Lily also added that observing and explaining was the type of writing she did most in science. "When we have to do our science notebook reflections, these are the kinds of things we always to write. We have to say what we saw using all five senses and explain what we learned based on what we saw."

The students were not sure what was being graded in the yearn and think section. Students came to the understanding that the think section was where they were explaining why they changed their initial designs. I showed the students Raven's response which indicated that her group chose to angle the blades so that they would catch the wind because she noted that during the first design the blades were all laying flat and not catching the wind. Her response included her observation that once Eve changed the angle that the blade was placed, it spun. This proved that she was able to pose an explanation as to why her group's windmill did not work, and was supported by evidence from her observations during the testing process. Nicole replied, "So what we have to write down is all the things that we talked about during the test." This wording helped to clarify for the students what was expected of them in the think component.

During the prediction reflection writing for the water filter challenge, Karina wanted to know if she could write about some of the ideas other people had discussed in class. She said she wasn't sure she could use them because they weren't her ideas. I stopped the class for a discussion about sharing ideas. We discussed the fact that engineers use ideas from several sources and individuals to come up with new solutions to problems. Lily remembered that "The redesign from the windmills was easier than the design because we were able to use what we saw from other groups. It was easier than coming up with the ideas all by ourselves." The class came to agreement that it would be ok to use someone else's idea in their prediction.

When the water filters were tested, two teams had filters that were significantly better than the others in terms of the amount of clear water they were able to produce. Rather than just focusing on what did work for the two successful filters the students were very eager to discuss similarities in the filters that did not work. Raven explained to the class that she wanted to know why the ones that didn't work failed so that she didn't include any of those ideas in her redesign. The class agreed with her thinking and the unsuccessful groups did not show any visible signs that they were upset that their designs did not work. They discovered that the use of cotton balls was not successful because the cotton absorbed almost all of the water and very little water would come out of their filter. They also noticed that the teams with lots of sand and soil or very small holes in the bottom of their filters were more successful in producing a large amount of clean water. This suggested to me that the students were yearning to learn more as they were asking questions to further their learning and suggesting alternatives to conduct further research.

After testing the students redesigned water filters, students were once again assigned to answer the guiding questions for writing a reflection. After grading the reflections, I noticed a discrepancy in the amount of detail in their discourse during the testing process versus the amount of detail in their writing. Several elements that were included in class discussion, such as asking questions and citing examples of effective and ineffective qualities, were not present in their writing.

When it came time for the students to produce their written reflections about the handheld pollinator design challenge, I noticed that for the first time not one person complained or asked why they had to write. Several students seemed eager to get down on paper what they had learned. I also witnessed for the first time students talking to their groups about what they were going to write before they actually starting writing. Prior to this the students had not talked at all while they were writing their reflections. I had told them that they were not allowed to talk during the reflection writing. The talking that was going on was related to the guided questions of the reflection.

When it came time to write the reflections for the moon lander project, none of the students complained or made protests. No students asked me for clarification on what to write or made comments about writing without receiving a grade. They were engaged in discourse as they were writing, which in turn led to greater details in their written responses. Their discussions focused on what they saw during the first and second tests, and what led to a successful roller coaster. This falls under the explain and think category of the writing. In future design challenges, I will encourage students to talk to their groups as they write their reflections. I could also allow them to work on their reflections during the class discussion of the results. I believe that this would lead to more detailed and complete responses.

Table 8 indicated the scores the students received on their final reflection piece.

Table 8 Last Journal Reflection Data

Name	Predict	Observe	Explain	Think	Reflect	Yearn
Lily	5	12	9	7	5	3
Karina	6	8	5	5	3	3
Ashley	6	7	8	6	7	3

Raven	12	12	7	11	10	4
Essence	7	8	8	4	4	4
Skyla	3	6	6	5	4	5
Jonah	7	9	5	7	7	3
Ryan	5	3	7	4	5	4
Binh	3	5	8	3	10	3
Hunter	3	7	6	8	6	3
Conner	5	3	4	5	9	6
Mikell	5	3	5	4	8	4
Christopher	3	4	8	3	5	3
Eve	6	6	10	6	7	5
Name	Predict	Observe	Explain	Think	Reflect	Yearn
Eibhlin	5	5	4	3	3	3
Travis	5	6	7	4	8	6
Bianca	4	6	5	3	3	3
Marcel	3	6	9	5	4	3
Nicole	4	11	5	8	9	4
Kimberly	3	5	7	3	4	3
Alejandro	5	8	5	4	6	5
Joseph	2	7	6	3	4	4
Mean:	4.86	6.68	6.65	5.04	5.95	3.81

Table 9 indicated the mean scores the students received on their first to last reflections.

Table 9 Written Reflection First and Last Means

Component	First Reflection Mean	Final Reflection Mean
Predict	4.5	4.86
Observe	6.86	6.78
Explain	6.41	6.54
Think	3.81	5.04
Reflect	5.95	5.95
Yearn	3.86	3.81

The only component of the students' written reflection that showed a growth was the think category. Based on class discussion after the first journal writing activity, I believe the students initially misunderstood what I wanted from them in this section. I started this action research project assuming that the students writing scores would increase as they completed more challenges. Based on the data I collected this assumption was not accurate for five of the six components of reflective writing that I measured. I believe that the reason behind this is that the participants of this action research study were all students considered at or above grade level in reading and math. It can thus be assumed that they were also on grade level for their writing ability. The students who participated in this action research study had completed science notebook reflections throughout all of third grade. I also believe, based on student conversations, that the fact that the students engineering journal scores did not affect their overall grades affected their motivation to improve their writing.

Observations did show that students ended this action research study with a more positive attitude toward the reflection process. Students came to see, and utilize, the advantage of referring to their predictions during their collaborations.

Summary

To sum up my findings of the data collected through survey pre and post test, writing reflection samples, teaching observations, and one-on-one interviews, I observed that students perceptions of engineers were affected by their completing a 10 week course where they participated in engineering design challenges. Students were more likely, after participating in design challenges, to classify an engineer as someone who helps people and performs mental tasks. Students who participated in engineering design challenges were also more likely to want to take a future class in engineering, pursue a career in engineering, and feel confident that they understood what an engineer does. A theme that emerged was that once students had a better understanding as to what an engineer actually did they were more likely to want to participate in engineering activities.

Students who participated in this study also expressed the view that they felt the level of friction between students decreased as a result of working in teams. This was verified through student interviews and teacher observation. A theme that emerged during the course of this action research was that students are more willing to work collaboratively if there is no grade attached to the work being done. I initiated this action research with the assumption that the groups would be more willing to work together over time as they saw that collaborative effort produced a better product.

The scores of the writing samples that the students produced did not show that the design challenges had an effect on writing ability. However, through teacher observation and student interviews, it was noted that students ended this action research project with a more positive attitude towards the need for engineers to complete journals where observations and thoughts were recorded.

Chapter five verified the literature that was reviewed for this study. It also explained the implications of elementary aged students participating in engineering design challenges. Limitations were discussed and further recommendations for study were addressed.

CHAPTER FIVE: CONCLUSION

Introduction

The purpose of this action research was to examine my practice of implementing engineering design challenges in my classroom and its effect on students' attitudes towards engineering, the classroom climate, and the students' written communication abilities. The focus questions invested through this action research were:

1. How did my practice of implementing engineering design challenges during a 4th grade enrichment class affect students' attitudes towards engineering and technology?
2. How did my practice of implementing engineering design challenges during a 4th grade enrichment class affect the classroom climate in regards to collaboration?
3. How did my practice of implementing engineering design challenges during a 4th grade enrichment class affect students' written communication skills?

Literature Review

For this action research study, students participated in five engineering design challenges over the course of 10 weeks. Cunningham and Lachapelle (2010), Hirsch, Carpinelli, Kimmel, Rockland, and Bloom (2007), Oware, Capobianco, and Diefus-Dux (2007) indicated that students who were not exposed to some sort of an engineering curriculum held misconceptions as to what an engineer does. This was corroborated in my findings as prior to completing the engineering design challenges the majority of participants in my study perceived engineers as someone who did physical work. Cunningham and Lachapelle's study (2005) showed that, even after being exposed to an engineering curriculum, fewer than one third of students recognized one of the central features of engineers as someone who designs. This was echoed in my own study, as prior to participating in the engineering design challenges only one student (5% of the total population) associated engineers with being someone who designs, and upon completion of the engineering design challenges five students (23% of the total population) identified an engineer as someone who designs.

Analysis of my findings also confirms the misconceptions held by students in one of the studies completed by Cunningham and Lachapelle (2005). Prior to having experience with an engineering curriculum students were likely to associate engineers with construction workers and auto mechanics. Cunningham and Lachapelle stateed that this misunderstanding is understandable as engineering has the word engine in it (2005).

Participants in Cunningham and Lachapelle's study (2010) showed that students who completed engineering design challenges were more likely to report interest in being an engineer on the posttest. They were also significantly more likely than students who did not complete design challenges to agree that scientists and engineers made people's lives better. The population of 4th grade students that participated in this action research study were also significantly more likely to say that they would enjoy being a scientist or an engineer after having completed engineering design challenges. The students who participated in this action research project were also significantly more likely to say that they thought they knew what engineers and scientists do for their jobs.

The President of the Accreditation Board for Engineering in 2001, Jerry Yeargan, had the notion that the students were not choosing to enter the engineering field because they were unaware of what engineering truly was (Gorham, 2002). Recent literature also felt that students were neglecting to enter the engineering field when they were a good fit for the field (Cook, 2009). He goes on to state that if students were more aware of what engineers did for a living they would be more likely to want to enter the engineering field. This was supported by the data I collected over the course of this action research project. After having completed five engineering design challenges over ten weeks, the students who participated in this study were also significantly more likely to say that they were interested in taking a future course on engineering. The questions “I think I know what engineers do for a job,” “I would like to be an engineer,” and “I would like to take a future course in engineering,” were all shown to have changes in the positive directions. This can be seen as evidence that the more comfortable students were in their perceptions of what an engineer does, the more likely they were to consider a possible career in engineering.

Limitations

One of the limitations to this study was regarding the makeup of the enrichment class. The twenty-two 4^{th} graders involved in this study were all students who had been shown, through state standardized testing, to be on grade level in reading. I believe that a population that included students that were considered below grade level would have shown a greater change in their writing ability than students who were already on grade level.

Another limitation, with regards to the student population, was that only two of the participants were on free and reduced lunch. This was not in correlation with the make- up of the school population. Cunningham (2010) and Hirsch, Carpinelli, Kimmel, Rockland, and Bloom (2007) both found that the population of students on free and reduced lunch showed a greater change in attitude towards engineering after completing engineering design challenges. Cunningham (2010) found the students on free and reduced lunch were more likely to believe, prior to completing an engineering curriculum that math and science did not have anything to do with real life. Based on the engineering attitude survey, the students in my study did not agree with the statement that math and science have nothing to do with real life. I believe the results to this particular question would have been different if my sample population included more students on free and reduced lunch.

Recommendations

Based on the results of this action research project, I plan on continuing to have the 4th grade students who are enrolled in the enrichment portion of iii complete engineering design challenges. I also plan on presenting my results to the school so that all elementary grade levels can see the benefit of these design challenges. Being that I am my school science lead, I am aware, that even though there is a quarterly design challenge assigned through the county curriculum for each elementary grade level, that most students in my school are not being exposed to any engineering curriculum. By encouraging each grade level to complete the required engineering component of the science curriculum all students, regardless of their reading level, would be able to participate in the design challenges. It would be interesting to see the results of an engineering attitude survey administered to a 4th grader who had been exposed to 4 design challenges every year since kindergarten. A long-term study comparing two schools, one who included an engineering component to the science curriculum and one who did not, would be interesting.

Another aspect of this study that had a big impact on my own belief was the reactions of the students as they completed their redesign. Last year, during my initial attempt to complete engineering design challenges, I neglected to let the students participate in a redesign and retest based on the results of their initial experiments. I remember students last year simply being frustrated with the challenges. I saw the same frustration during the first test of the participants' windmills. The students felt like failures when the technology they designed did not work as they expected. However, once the students in this action research study realized that they could learn from the failed product to make an improved one, their attitudes improved. During none of the subsequent trials were students visibly upset if their technology did not perform as desired.

Another aspect of this study that I would be interested in seeing investigated would be the attachment of grades to the projects. Through conversations with my students I felt that the reason they were willing to help other groups and share ideas was the fact that there was no grade attached to their final product. I would anticipate that students would be less reluctant to take risks, and more upset when a project did not work, if there was a grade attached to the outcome. I also believe that grading the students' written responses would have a positive effect on the quality of their work.

One last aspect of this study that I would like to investigate further is whether or not completing the engineering design challenges increased student knowledge of science benchmarks. My observations showed me that students were very excited to complete the moon lander design challenge because we had just finished studying the space race in science class. If the engineering design challenges were completed at the end of a correlating science unit it could be seen as an extension activity for science. An example of this would be the hand held pollinator challenge. I would like to administer a pretest about pollination to students after I had taught about pollination in class but before they had completed the design challenge. I would then like to administer a posttest about pollination to students after they had completed the design challenge to see if their scores based on the benchmark of pollination had increased.

Implications

According to the findings of this action research study, one of the implications could be that exposing students to engineering during elementary schools may lead to a greater number of students going into the engineering field in college. As evidenced through the attitude survey and the student provided definitions of an engineer, students who participated in the engineering design challenges were more confident and accurate in their beliefs as to what an engineer does. Hirsch, Carpinelli, Kimmel, Rockland, and Bloom (2007) would support this implication, as their study showed that students who had been exposed to engineering before college showed a greater interest in pursuing a career in engineering. More students pursuing engineering majors and careers would be a positive thing in that the demand for engineers has expanded, but the rate of graduates in the engineering field has stayed flat or declined.

Summary

The purpose of this action research study was to determine whether having 4th grade students participate in engineering design challenges would have an impact on their attitudes towards engineers, the classroom environment, and the students' writing abilities. Pre and posttests were analyzed for all three questions. Having 4th grade students participate in engineering design challenges for 10 weeks did have a positive impact on their attitudes towards engineering. The data also showed that the students who previously believed that engineers were people who worked on trains and cars, were able to dispel this notion after completion of the course. The data also demonstrated that students were more satisfied with their enrichment course and felt that the level of friction in the classroom had decreased upon completion of the action research study. The study did not show that my practice of implementing engineering design challenges had an effect on the quality of students' written responses.

APPENDIX A: IRB PERMISSION

University of Central Florida

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Approval of Human Research

From: **UCF Institutional Review Board #1**
FWA00000351, IRB00001138

To: **Tara L. Newby**

Date: **August 03, 2011**

Dear Researcher:

On 8/3/2011, the IRB approved the following human participant research until 8/2/2012 inclusive:

Type of Review:	UCF Initial Review Submission Form
Project Title:	The implementation of Engineering Design Challenges on 4th grade students and its effects on students' attitudes towards engineering and their written communication and collaboration skills
Investigator:	Tara L Newby
IRB Number:	SBE-11-07779
Funding Agency:	
Grant Title:	
Research ID:	NA

The Continuing Review Application must be submitted 30days prior to the expiration date for studies that were previously expedited, and 60 days prior to the expiration date for research that was previously reviewed at a convened meeting. Do not make changes to the study (i.e., protocol, methodology, consent form, personnel, site, etc.) before obtaining IRB approval. A Modification Form **cannot** be used to extend the approval period of a study. All forms may be completed and submitted online at https://iris.research.ucf.edu .

If continuing review approval is not granted before the expiration date of 8/2/2012, approval of this research expires on that date. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

Use of the approved, stamped consent document(s) is required. The new form supersedes all previous versions, which are now invalid for further use. Only approved investigators (or other approved key study personnel) may solicit consent for research participation. Participants or their representatives must receive a copy of the consent form(s).

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

On behalf of Kendra Dimond Campbell, MA, JD, UCF IRB Interim Chair, this letter is signed by:

Signature applied by Joanne Muratori on 08/03/2011 08:51:00 AM EDT

Joanne Muratori

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APPENDIX C: PRINCIPAL CONSENT

ORANGE COUNTY PUBLIC SCHOOLS
2900 LOGANDALE DR. ORLANDO, FL 32817
407/672-3110 FAX 407/672-1310

Paige Tracy, Principal

July 12, 2011

To Whom It May Concern:

I am writing this letter in support of Tara Newby, a 4th grade teacher at Arbor Ridge K-8 School. I am aware of her upcoming action research project, Engineering Design Challenges, for her thesis project at UCF. Tara has my full support of engaging the students in designing their engineering challenges as an authentic learning tool to enhance the science curriculum for her classroom during the 2011-2012 school year. She is a professional and will act in the best interest of her students for this action research.

Sincerely,

Paige Tracy

Paige Tracy

Principal

The Orange County School Board is an equal opportunity agency

APPENDIX D: PARENT CONSENT

The Implementation of Elementary Engineering Design Challenges and the effects it has on

student's perception of engineers and the classroom environment

Informed Consent

Principal Investigator(s):	*Tara L Newby*
Faculty Supervisor:	Bobby Jeanpierre, PhD
Sponsor:	University of Central Florida
Investigational Site(s):	*Arbor Ridge K-8 School* *2900 Logandale Drive* *Orlando, FL 32817*

Researchers at the University of Central Florida (UCF) study many topics. To do this we need the help of people who agree to take part in a research study. You are being asked to allow your child to take part in a research study that will include about *22* students. Your child is being invited to take part in this research study because he or she is a student at Arbor Ridge School enrolled in Mrs. Newby's 4th grade enrichment class.

Tara L. Newby, 4th grade teacher, will be conducting the research. She is a graduate student of the UCF Lockheed-Martin Math and Science program. Mrs. Newby's faculty supervisor in this study is Dr. Jeanpierre in the Teaching and Learning Principles department. Dr. Jeanpierre will guide Mrs. Newby through this action research study.

How to return this consent form to the teacher:

- Carefully read all information.
- If consent is granted, please sign the signature page and return to the classroom teacher.

- Please return the signature page of this consent form by September 16, 2011.

What you should know about a research study:

- Someone will explain this research study to you.
- A research study is something you volunteer for.
- Whether or not you take part is up to you.
- You should allow your child to take part in this study only because you want to.
- You can choose not to take part in the research study.
- You can agree to take part now and later change your mind.
- Whatever you decide it will not be held against you or your child.
- Feel free to ask all the questions you want before you decide.

Purpose of the research study: *The purpose of this study is to determine how the implementation of engineering design challenges affects students' attitudes towards engineering, their written communication abilities and the classroom environment with regards to collaboration.*

What your child will be asked to do in the study: As part of your student's enrichment curriculum, your student will be asked to complete engineering design challenges. Prior to starting the challenges your student will be given two surveys. The first is an interest and attitudes survey about technology and engineering. The second survey is called My Class Inventory and it will measure the students' perceptions of the class environment. Your child does not have to answer every question or complete every task. You or your child will not lose any benefits if your child skips questions or tasks. Students will then be instructed about the engineering design process. Students will be put in to teams and will be presented with a real world problem and asked to design a piece of technology to solve that problem. When they are finished they will be required to produce a written explanation and diagram of their solution. I expect to complete 4-5 design challenges. After each challenge their written explanations and diagrams will be scored via a rubric to measure their writing ability. This will not be a grade. Throughout the study your child will be interviewed about their perceptions of engineers and their feelings on working collaboratively. At the completion of the study (just prior to winter break) your child will once again complete the interest and attitudes survey about technology and engineering and the My Class Inventory. There are no expected risks to taking part in this study.

Location: *All research will be conducted at Arbor Ridge K-8 school.*

Time required: We expect that your child will be in this research study for approximately 9-12 weeks. The study will be completed for half an hour each day during the 4th grade enrichment block.

Audio or video taping:

Your child will be audio taped during this study. If you do not want your child to be audio taped, your child will still be able to be in the study. Discuss this with the researcher or a research team member. If your child is audio taped, the tape will be kept in a locked, safe place. The tape will be erased or destroyed *at the end of the school year.*

Your child will be video taped during this study. If you do not want your child to be video taped, your child will still be able to be in the study. Discuss this with the researcher or a research team member. If your child is video taped, the tape will be kept in a locked, safe place. The tape will be erased or destroyed *at the end of the school year.*

Benefits:

We cannot promise any benefits to you, your child, or others from your child taking part in this research. However, possible benefits may include :

- More focused writing in Science
- Ability to produce more detailed diagrams
- Better understanding of engineering and technology
- Knowledge of the engineering design process
- Development of a positive attitude towards engineering and technology
- Development of a positive attitude toward group collaboration
- Ability to use problem solving skills in a real world context

Voluntary participation:

You should allow your child to take part in this study only because you want to. There is no penalty for not taking part, and neither you nor your child will lose any benefits. The engineering content used in this study will be taught regardless of your child's participation. If you choose to decline participation for your child, their results from the two surveys will not be used. The data derived from their writing samples will not be used in the study. You have the right to stop your child from taking part at any time. Just tell the researcher that you want your child to stop. Participation or non participation will not affect any of your child's grades.

Compensation or payment:

There is no compensation, payment or extra credit for your child's part in this study

Study contact for questions about the study or to report a problem: If you have questions, concerns, or complaints, talk to *Tara Newby:* tara.newby@ocps.net or (407)672-3110 ext. 4289

IRB contact about you and your child's rights in the study or to report a complaint: Research at the University of Central Florida involving human participants is carried out under the oversight of the Institutional Review Board (UCF IRB). This research has been reviewed and approved by the IRB. For information about the rights of people who take part in research, please contact: Institutional Review Board, University of Central Florida, Office of Research & Commercialization, 12201 Research Parkway, Suite 501, Orlando, FL 32826-3246 or by telephone at (407) 823-2901. You may also talk to them for any of the following:

- Your questions, concerns, or complaints are not being answered by the research team.
- You cannot reach the research team.
- You want to talk to someone besides the research team.
- You want to get information or provide input about this research.

Your signature below indicates your permission for the child named below to take part in this research.

DO NOT SIGN THIS FORM AFTER THE IRB EXPIRATION DATE BELOW

Name of participant

Signature of parent or guardian

Date

- ❑ Parent
- ❑ Guardian (See note below)

Printed name of parent or guardian

APPENDIX E: STUDENT ASSENT

Child Assent Script

My name is Mrs. Newby. I am doing research at the Univeristy of Central Florida about doing engineering in the elementary classroom. In enrichment class we will be completing engineering design challenges and I will be asking you questions about how you feel about engineering, how you feel about the class and working in groups, and looking at your final written projects.

The work you do during enrichment class will not affect your grade and you will not receive extra credit for doing it. It is an opportunity for you to learn about engineering and solving real world problems. Would you like to take part in this research project?

__________ I want to take part in Mrs. Newby's research project

_________________________________ _______________________________

Student's Signature Date

____

Student's Printed Name

APPENDIX F: POETRY RUBRIC

Version C

P.O.E.T.R.Y.

Predict ★Observe ★Explain ★Think ★Reflect ★Yearn

4 = Advanced 3 = Proficient 2 = Basic 1 = Developing

Predict:

1. The prediction is related to the topic at hand.	4	3	2	1
2. Student uses evidence to make prediction.	4	3	2	1
3. Student explains basis for making prediction.	4	3	2	1

Observe:

1. Student uses several senses to explore objects.	4	3	2	1
2. Student identifies patterns or relationships.	4	3	2	1
3. Identifies details in objects.	4	3	2	1

Explain:

1. Student poses a possible explanation.	4	3	2	1
2. Explanation is supported by prior knowledge.	4	3	2	1
3. Explanation is supported by evidence from observations.	4	3	2	1

Think:

1. Student poses a reasonable alternative explanation.	4	3	2	1
2. Alternative explanation is supported by prior knowledge.	4	3	2	1
3. Alternative explanation is supported by evidence from observations.	4	3	2	1

Reflect:

1. Student explains possible sources of error or inaccurate records.	4	3	2	1
2. Student provides ideas of how to improve data collection.	4	3	2	1
3. Student reflects on own behavior in process.	4	3	2	1

Yearn:

1. Student asks new questions to extend learning.	4	3	2	1
2. Student suggests further areas of related research.	4	3	2	1
3. Student provides reasonable methods for conducting further research.	4	3	2	1

APPENDIX G: POETRY RUBRIC PERMISSION

Re: P.O.E.T.R.Y. of science – Outlook Web Access Light 7/22/11 10:40 AM

Office Outlook Web Access | Type here to search | This Folder | Address Book | Options | Log Off

Mail | Reply | Reply to All | Forward | Move | Delete | Close

Deleted Items (1)
Drafts [8]
Inbox
Junk E-mail
Sent Items

Click to view all folders

Eagle Letter
Jennifer, Paige, Jan, Je...
Team Information
thesis UCF

Manage Folders...

Re: P.O.E.T.R.Y. of science

Jones,Linda Lee Ann [lcjones@coe.ufl.edu]

Sent: Thursday, July 21, 2011 9:33 PM

To: Newby, Tara L.

Hi Tara,
You are welcome to use the rubric. We just ask thar you acknowledge Klosterman, Mesa, and Jones as the authors of the rubric when reporting your research!

Best,
Dr. Jones

Sent from my iPhone

On Jul 21, 2011, at 5:25 PM, "Newby, Tara L." <tara.newby@ocps.net> wrote:

> Hello,
>
> I am a graduate student at the University of Central Florida. I am
> currently in the Lockheed-Martin Math and Science scholar program.
> In conducting my research for my thesis topic, I've read your
> article on The P.O.E.T.R.Y. of Science.
>
> I would like to ask permission to use the rubric for my action
> research. One aspect of my action research is on the engineering
> design process and how design challenges can effect students written
> communication abilities.
>
> Your response would be greatly appreciated.
>
> Tara Newby
> Arbor Ridge School
> Orlando, FL
>
> --
> The information contained in this e-mail message is intended solely
> for
> the recipient(s) and may contain privileged information. Tampering
> with
> or altering the contents of this message is prohibited. This
> information
> is the same as any written document and may be subject to all rules
> governing public information according to Florida Statutes. Any
> message
> that falls under Chapter 119 shall not be altered in a manner that
> misrepresents the activities of Orange County Public Schools.
> [References: Florida State Constitution I.24, Florida State Statutes
> Chapter 119, and OCPS Management Directive A-9.] If you have received
> this message in error, or are not the named recipient notify the
> sender
> and delete this message from your computer.

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APPENDIX I: MY CLASS INVENTORY

Name ___________________________________

My Class Inventory

Directions: This is not a test. This is to find out about your class. Draw a circle around

Write YES if you AGREE with the sentence

Write NO if you DON'T AGREE with the sentence.

If you change your mind about a response, cross it out and circle the new response.
Respond to the statements as your classroom actually is OR as you prefer your classroom to be. (Your teacher will tell you which to use.)

This Is How I Think About My Classroom

1. Students enjoy their schoolwork in my class.
2. Students are always fighting with each other.
3. Students often race to see who can finish first.
4. In our class the work is hard to do.
5. In my class everyone is my friend.
6. Some students are not happy in class.
7. Some of the students in our class are mean.
8. Most students want their work to be better than their friends' work.
9. Most students can do their schoolwork without help.
10. Some people in my class are not my friends.
11. Students seem to like the class.
12. Many students in our class like to fight.
13. Some students feel bad when they don't do as well as the others.
14. Only the smarter students can do their work.
15. All students in my class are close friends.
16. Some of the students do not like the class.
17. Certain students always want to have their way.
18. Some students always try to do their work better than the others.
19. Schoolwork is hard to do.
20. All of the students in my class like each other.
21. This class is fun.
22. Students in our class fight a lot.
23. A few students in my class want to be first all the time.
24. Most of the students in my class know how to do their work.
25. Students in our class like each other as friends.

S ____ F ____ Cm ____ D ____ Ch ____

APPENDIX K: ENGINEERING ATTITUDE SURVEY PERMISSION

Office Outlook Web Access | Type here to search | This Folder | Address Book | Options | Log Off

Mail

Deleted Items (1)
Drafts [8]
Inbox
Junk E-mail
Sent Items

Click to view all folders

Eagle Letter
Jennifer, Paige, Jan, Je...
Team Information
thesis UCF

Manage Folders...

Reply | Reply to All | Forward | Move | Delete | Close

RE: Engineering Attitudes Survey

Christine Cunningham [ccunningham@mos.org]

Sent: Friday, July 22, 2011 9:45 AM

To: Newby, Tara L.

This is fine. Best of luck with your research--I'd be interested in what you find.
Christine

Christine M. Cunningham, Ph.D.
Founder & Director, Engineering is Elementary
Vice President, Museum of Science
www.mos.org/eie
Museum of Science
1 Science Park
Boston, MA 02114
phone: (617) 589-0255
fax: (617) 589-3110

-----Original Message-----
From: Newby, Tara L. [mailto:tara.newby@ocps.net]
Sent: Thursday, July 21, 2011 5:23 PM
To: ccunningham@mos.org
Subject: Engineering Attitudes Survey

Good afternoon,

I am a graduate student at the University of Central Florida and am currently enrolled in the Lockheed Martin Math and Science program. I am currently doing research for my thesis topic and upcoming action research and would like permission to use the engineering and science attitude scale used in the paper: The Impact of Engineering is Elementary on Students' Attitudes Towards Engineering and Science. I would also like to reference the EiE lessons and the engineering design process image. Our county currently uses your program as part of our curriculum. I would site the program and the article in my work.

Please do not hesitate to ask me any questions. Thank you in advance for your reply.

Tara Newby
4th Grade Teacher
Arbor Ridge School
Orlando, FL

Connected to Microsoft Exchange

APPENDIX L: DESCRIPTION OF DESIGN CHALLENGES

Table 10 Description of Design Challenges

Title	Description
Windmill	Students were required to design windmill blades that could be used to effectively lift a load of at least 10 pennies. They were provided with a half gallon milk carton base that had a wooden dowel pierced through both sides. Attached to the wooden dowel was a 3 inch Styrofoam ball on to which students needed to attach their blades. Students were allowed access to felt, aluminum foil, cardboard, card stock, tissue paper, toothpicks, pipe cleaners, Styrofoam plates, Dixie cups, printer paper, tape, flexible drinking straws, coffee stirrers, and saran wrap. Teams of 3 to 4 students drew blueprints and were provided with the materials listed on the blueprint. After the teams received their materials they built their windmill blades according to their blueprints. The windmills were then tested and students repeated the process during their redesign. Students wrote reflections prior to building and after the rebuild based on questions that were provided.
Water Filter	Students were provided with water that was contaminated with vegetable oil, black tempera paint, coffee, dish detergent, shredded tissue paper, and blue food dye. Student teams were required to develop a water filter that would produce clean looking water. The students were provided with 2 liter bottles, aquarium gravel, dry sand, cat liter, activated charcoal, sponges, potting soil, coffee filters, cotton balls, felt squares, cotton cloth, masking tape, and a 2 liter rectangular Tupperware container. The student teams each produced one blueprint that was signed off by each member of the team. The groups were provided with the materials their blueprints listed and allowed to build their water filter prototype. The water filters were tested in front of the class. The students were then allowed to redesign and rebuild their water filter. Students wrote reflections prior to building after the rebuild based on questions that were provided.
Hand Held Pollinator	Students were first given a lesson on pollination. They were then presented with a problem that a gardener had noticed that the number of bees present has been declining and he needed to produce a cheap, but effective, hand held pollinator. Students were shown a poppy type flower that would need to be pollinated. They were given a list of materials and prices. The materials and prices were: list here The student teams had to design a blueprint for the cheapest, but most effective, handheld pollinator they could design. Once the team

	agreed on a blueprint and materials list they were given the materials listed on the blueprint. Once all teams finished designing the handheld pollinators were tested by dipping the pollinator in a pile of cornstarch once and then applying it to the model of the flower. Students took note of how much pollen was transferred and how evenly the pollen was transferred. The students also discussed the cost of each pollinator. After reflection students re-designed their pollinators, aiming to produce one that was cheaper and more effective than their first. The redesigned pollinators were then again tested. Students wrote reflections prior to building and after the rebuild based on questions that were provided.
Moon Lander	Students were required to designed a shock absorbing landing system for a moon lander. The moon lander was a 4x6 inch index card with a 4 oz Dixie cup taped to the center. Inside the Dixie cup were 2 jumbo sized marshmallows. The students were provided with 8 flexible straws, 10 mini marshmallows, 3 index cards, and 4 rubber bands with which to create a shock absorbing landing system for the moon lander. The lander would be dropped from a height of 36 inches. Upon landing the 2 jumbo marshmallow astronauts could not bounce or fall out of the Dixie cup. The groups' initial designs were tested in front of the class and the results discussed. Each group then redesigned and rebuilt their moon lander. The students wrote reflections prior to building and after the rebuild based on questions that were provided.
Roller Coaster	Students were required to use a limited number of provided materials to build a roller coaster track on which a marble could travel. Completed roller coasters would receive a certain number of points for meeting certain criteria. Roller coasters would receive 1 point for each centimeter of height, 5 points for each right angle, 1 point for each successful run where a marble successfully making it all the way down a roller coaster track, and 5 points for a marble successfully making it all the way down the roller coaster track and landing in a target area. The materials provided were 5 4x6 inch index cards, 10 straws, 10 q-tips, 24 inches of masking tape, and 3 ounces of modeling clay. Student groups were also given a time limit of 25 minutes for planning and 25 minutes for building their roller coaster tracks. The roller coasters were tested by running a marble down the track 3 times and adding up all accumulated points. The results were discussed and teams were given an additional 25 minutes to redesign and 25 minutes to rebuild prior to retesting. The students wrote reflections prior to building and after the rebuild based on questions that were provided.

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