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Progressing Science, Technology, Engineering, And Math (STEM) Education In North Dakota With Near-Space Ballooning

Marissa Elizabeth Saad

PROGRESSING SCIENCE, TECHNOLOGY, ENGINEERING, AND MATH (STEM) EDUCATION IN NORTH DAKOTA WITH NEAR-SPACE BALLOONING

by

Marissa Elizabeth Saad
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This thesis, submitted by Marissa Saad, in partial fulfillment of the requirements for the Degree of Master of Science from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done and is hereby approved.

Ronald A. Fevig 4/23/14
Dr. Ron Fevig

4/23/2014
Dr. Paul Hardersen

Dr. Gail Ingwalson 4/23/14
Dr. Gail Ingwalson

This thesis is being submitted by the appointed advisory committee as having met all of the requirements of the School of Graduate Studies at the University of North Dakota and is hereby approved.

Wayne S. Swisher
Wayne Swisher
Dean of the School of Graduate Studies

April 28, 2014
Date

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Marissa Saad
April 23, 2014

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ABSTRACT

The United States must provide quality science, technology, engineering, and math (STEM) education in order to maintain a leading role in the global economy. Numerous initiatives have been established across the United States that promote and encourage STEM education within the middle school curriculum. Integrating active learning pedagogy into instructors' lesson plans will prepare the students to think critically – a necessary skill for the twenty first century.

This study integrated a three-week long Near Space Balloon project into six eighth grade Earth Science classes from Valley Middle School in Grand Forks, North Dakota. It was hypothesized that after the students designed, constructed, launched, and analyzed their payload experiments, they would have an increased affinity for high school science and math classes.

A pre- and post-survey was distributed to the students (n=124), before and after the project to analyze how effective this engineering and space mission was regarding high school STEM interests. The surveys were statistically analyzed, comparing means by the Student's t-Test, specifically the Welch-Satterthwaite test. Female students displayed a 57.1% increase in math and a 63.6% increase in science; male students displayed a 46.6% increase in science and 0% increase in math. Most Likert-scale survey questions experienced no statistically significant change, supporting the null hypothesis. The only survey question that supported the hypothesis was, "I Think Engineers Work Alone," which experienced a 0.24% decrease in student understanding. The results suggest that integrating a three-week long Near Space Balloon project into middle school

curricula will not directly influence the students' excitement to pursue STEM subjects and careers. An extensive, yearlong ballooning mission is recommended so that it can be integrated with multiple core subjects. Using such an innovative pedagogy method as with this balloon launch will help students master the scientific process and experience real team collaboration, as they did in this successful mission.

To my
Mom Marylou, dad John,
Brother Johnny, and sister Christine,
My most loving and supportive family.
And to Ben March, I wouldn’t have
Been able to do any of this
Without you

CHAPTER I

INTRODUCTION

In order to maintain a leading role in the global economy, the United States must maintain its dominance in STEM education. American education is rapidly falling behind its Asian competitors, providing students with fewer opportunities that could establish cutting-edge innovations (National Science Board, 2010). There are many initiatives across the United States that are attempting to improve its K-12 standings in STEM education. New academic reforms are being introduced into the middle school curriculum, providing students with hands-on and engaging activities. In order for the U.S. to become the global leader in education, the students must use critical thinking skills and fundamentally understand the scientific method. Once students are able to think critically, they can apply their knowledge in all areas of their education, future careers, and lives.

In an effort to inspire middle school students to STEM subject, this thesis study provided 115 eighth grade students from Valley Middle School in Grand Forks, North Dakota, with his or her own near space balloon (NSB) mission. The North Dakota Space Grant Consortium (NDSGC) provided these middle school students with a unique opportunity to work in teams and develop a scientific experiment. These experiments flew onboard two NSBs, surpassing 102,000 feet (31 km) in altitude. This NSB activity combined how to use critical thinking and the scientific process in a real-world activity. In twelve teams, the students designed, constructed, and flew science experiments while collaborating together. The NSB project reinforced science content already covered in their science class and modeled how engineering teams interact in real life.

Statement of the Problem

The United States of America is rapidly falling behind in the global standings of STEM education. America needs to implement different learning methods to K-12 students that will prepare them for the competitive world. This NSB project will show the students how to execute a real science mission, master the framework of the scientific process, and increase their enthusiasm for science.

Hypothesis

Middle school students who have practiced the scientific method in a real world application of Near Space Ballooning will have an increased affinity to study STEM subjects in their future.

CHAPTER II

A REVIEW OF THE LITERATURE

Numerous initiatives have been established across the United States that promote and encourage STEM education within middle school curricula (Pecen & Humston, 2012; Sirinterlikci, Zane, & Sirinterlikci, 2009; Nugent, G., Barker, B., Grandgenett, N., & Adamchuk, V. I., 2010; Klahr, Triona & Williams, 2006). These studies examined the impact that inquiry-based and hands-on learning had upon the targeted students. Active-learning pedagogy is an instructional method that will prepare students for careers that will require critical thinking. This study incorporated techniques and lessons learned from reviewing the literature into her the NSB study.

Nationwide Economic Struggles

An important driver for the twenty-first century is science and technology advancements. The United States is providing adequate science education and failing to keep up with our European and Asian competitors (National Science Board, 2010). Therefore, we need to provide quality STEM education to be able to keep up with the high-tech global economy. In order to improve our level of science proficiency, more focus has been placed on STEM initiatives in the middle school curricula (DeJarnette, N. K., 2012). It has been proven that the best time to expose students to STEM activities and strengthen their connection is at this young age (DeJarnette, N. K., 2012).

In the past decade, the number of students enrolling in high school STEM classes has risen, according to the Federal Interagency Forum on Child and Family Statistics

(2011). The number of undergraduate students enrolled in four-year institutions has also risen. Despite this growth, the rate of the increase lags behind other developed countries (DeJarnette, N. K., 2012). Over half of the Natural Sciences and Engineering doctorate degrees earned in the United States since 2006 were awarded to Asian students (National Science Board, 2010).

A study presented at the 2005 American Astronomical Society (AAS) meeting took a survey of STEM related questions and targeted them at U.S. citizens. Some results included:

- 75 percent of *middle school science teachers* did not know that the speed of radio waves is the same as the speed of light
- 20 percent of U.S. adults could not answer, “does the Earth go around the Sun or Sun around Earth?”
- 78 percent of U.S. adults cannot define “molecule”
- 63 percent of U.S. adults think that lasers work by focusing sound waves
- 47 percent of U.S. teens could not convert “nine-tenths” to a percentage

(Klug, Sharp, & Jackson, 2006)

Fewer opportunities exist for students and their teachers to explore STEM activities (DeJarnette, N. K., 2012). Therefore, it is this Valley Middle School (VMS) study’s goal to help provide resources and activities to help alter the middle school student’s dispositions about science and technology. Exposing students to STEM subjects early in their academic careers is essential to the level of understanding necessary in higher education (DeJarnette, N. K., 2012).

After the Soviet Union launched Sputnik, the world's first satellite, in 1957, America launched one of the largest research and experimentation reforms in education history (Herschbach, 1996). Present day educators meet similar circumstances regarding America's ranking in education. The major difference is the presence of technology in grades K-5. The "T" and "E" in "STEM" will play a critical role to America's welfare in this twenty-first century (Sanders, 2009).

The National Science Foundation (NSF) created the STEM acronym, although initially called "SMET" (Science, Mathematics, Engineering, and Technology). By 2003, relatively few knew of this new education approach (Sanders, 2009). Soon after, the book "The World is Flat," revealed to all Americans of how rapidly China and India were "outSTEMming" us (Freidman, 2005). Their global economy was on a course that would quickly surpass America's (Sanders, 2009).

Over the last twenty five years, all four STEM education subjects have experienced multiple ongoing educational reform efforts, as a response to the competition (Sanders, 2009). These reforms include: *Project 2061: Science for All Americans* (AAAS, 1989, 2003); the *National Science Education Standards* (NRC, 1996); *International Technology Education Association (*ITEA, 1996, 2000, 2002, 2007*); ABET Criteria for Accrediting Engineering Programs (*ABET, 2004*); National Science Education Standards* (NRC, 1994); *No Child Left Behind (*NCLB, 2001*);* and *Educate to Innovate (*The White House, 2009).

Active Learning

Active learning is defined as a method of teaching that engages students in the learning process (Prince, 2004). It is “often presented or perceived as a radical change from “traditional instruction” and “frequently polarizes faculty” – faculty who may believe their traditional style of teaching is already “active” through homework and laboratories (Prince, 2004). The inquiry-based method allows students to apply what they have experienced to real life scenarios. Through active learning, students are able to boost their self-confidence, improve collaborative skills, and are less intimidated to approach math material. Laws, Sokoloff, & Thornton proved that conceptual learning of physics needed to be “activity-based, computer-supported, [and] interactive” (1999). The ballooning mission is the culmination of a hands-on project, utilizing computers, technical equipment, and team collaborations.

Traditionally, science and math are taught in a didactic manner and students take notes through a lecture setting (Sirinterlikci, A., Zane, L., & Sirinterlikci, A. L., 2009). Prince (2004) confirmed that students are unable to learn from this ineffective, passive technique. “Teaching by telling” is an ineffective mode of instruction for most students (Laws, Sokoloff, & Thornton, 1999).

Methods to Promote Active Learning

Collaboration between the University of Oregon and Tufts University produced an “interactive lecture demonstration,” studying college student learning in physics (Prince, 2004). Their method of teaching kinematics (force, acceleration, and velocity) is applicable to our approach with middle school students. This study was conducted at five different universities. After traditional instruction, 30 percent of a sample of over 1200 students in calculus-based physics courses understood these basic concepts. When the same laboratories were offered at different universities, over 75 percent of the students understood the concepts (Prince, 2004). Universities that implemented complete active-learning laboratories yielded 93 percent understandability. They distributed “prediction sheets” and “results sheets”—their formula for evaluating the students.

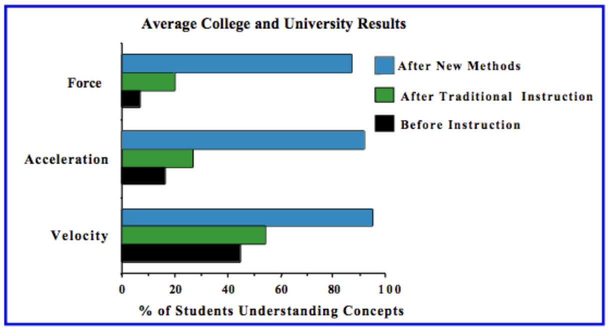


Figure 1: Average Results with Understanding Concepts

Prince (2004) tested the effect of traditional versus active teaching. Traditional instruction (green bars) were able to change the minds of students. Active learning (real hands-on demonstrations and technology usage) resulted in students understanding concepts (blue bars). Pretest scores, before instruction, are in black.

This study aims to produce results with lessons learned through the student balloon payloads, similar to those shown above. The kinematics study followed these effective steps: first, they described the demonstration, asked for student predictions, held small group discussions, asked for final predictions, and finally carried out the demonstration. A class discussion completed the assignment.

One of the most helpful and informative studies discovered in this literature review was the application and guidance of active learning through toy design and development, called the TOYchallenge National Design Competition by Sally Ride Science. (Sirinterlikci et al., 2009). Almost completely analogous to our own NSB endeavor, this case study held a competition for middle school students (grades 5-8) in teams of 3-6 members to design, develop, and construct their own "toy". Each toy design had to follow three rules: (1) the toy could not have been entered in a previous competition; (2) the toy cannot contain pieces from an existing commercial toy; and (3) the toy needed to fulfill one of three possible categories. These categories included: (1) *Get Out and Play* (promoting outdoor activities); (2) *Games for the Family* (games designed for the whole family to enjoy); and (3) *Toys that Teach* (toys that can be used in teaching people of all ages) (Sirinterlikci et al., 2009).

In their case, the toy encouraged and promoted ways to learn about the design process of science and engineering material (Sirinterlikci et al., 2009). The toy model functions in the same way as the VMS payloads. The students will experience the same concepts: define the objective of the payload, conduct research on how to tackle a problem, brainstorm, draw a prototype design, test and evaluate the design, and communicate the results to peers (Sirinterlikci et al., 2009).

The method Sirinterlikci, Zane, and Sirinterlikci performed to evaluate the students was taken in advisement by This thesis study. In order to quantitatively see the results of the study, Sirinterlikci et al. evaluated the effectiveness of the inquiry-based, hands-on, and active learning style by having the students fill out before-and-after questionnaires (2009).

Student cooperation, communication, and creativity were key to this study. The preliminary entry report, given to all students, was similar to an engineering design proposal (Sirinterlikci et al., 2009). Their report consisted of many criteria. Some of the following:

1. What category did you choose? (Name and objective of toy)
2. How does it work? (Explain the specifics)
3. Your team (How the team worked together to develop ideas)

   (How they divided up the responsibilities and completed it)
4. The design process
5. Photos/Sketches of the product
6. Preliminary Round Entry Budget

This study drew an interesting conclusion about student genders. They found groups of entirely female students submitted game topics with less action and more learning, and entirely male groups focused on "male-favored activities" (Sirinterlikci et al., 2009). This observation will be analyzed using the student balloon teams.

At the end of the competition, the students presented their findings. This is a great teaching method to prepare them for upper level science classes. The final questions given to the students were designed to gauge the students' perceptions of engineering concepts (Sirinterlikci et al., 2009). This final toy survey directed and influenced the style of questions we will use for the balloon project. The engineering survey was designed to see if time spent engaged in active learning and project development dispelled any myths or preconceived ideas regarding STEM careers—engineering in particular. The questions asked are below, as well as the numerical value:

1. Engineers probably have interesting stories to share about their work. (Value of 4)
2. Engineering is boring. (Value of 2)
3. It would be fun to be an engineer. (Value of 4.4)

4. I think I will take engineering classes in college. (Value of 3)
5. I might pursue a career in engineering. (Value of 3)
6. Engineers usually work alone on projects. (Value of 4)
7. Most people my age think engineering is cool. (Value of 3.3)

Answers were submitted on a scale of one to seven (one representing "strongly disagree" and seven representing "strongly agree") (Sirinterlikci et al., 2009). Most students did not think engineering was boring, which could reflect a positive outcome due to this STEM project, even if they did not expect to become an engineer in college or in their career.

Another survey was given to the students, sampling their understanding and comfort level with using technology (Sirinterlikci et al., 2009). The three questions consisted of:

1. Comfortable using technology. (Value of 3.6)
2. Comfortable using the engineering design. (Value of 2.6)
3. Comfortable building things. (Value of 4.5)

Another program, at the University of Nebraska, used robotics and geospatial technologies to promote engaging, hands-on, and inquiry-oriented STEM learning for a group of 147-middle school students. (Nugent, Barker, Grandgenett, & Adamchuk, 2010). They held two learning sessions: a forty-hour intensive robotics, global positioning system (GPS), and geographic information systems (GIS) summer camp, and a three-hour introductory class modeled on the camp experiences. The longer summer session produced greater learning, and the students gained a thorough understanding of

STEM concepts. The three-hour class session impacted youth attitude and motivation regarding STEM (Nugent et al., 2010). Robots designed through this study (equivalent to our technological payloads) enhanced the traditional classroom oriented learning process. The abstract math and science concepts were translated into real world applications that the students could understand (Nugent et al., 2010).

This robotics study has provided extra interactive techniques that our students could perform. These may consist of manually plotting the balloon's progress (while in the car) on provided maps. This would provide experience using longitudinal and latitudinal coordinates. They also interact with the concept of remote sensing. Images captured onboard the balloon with cameras or payload video cameras detect landmarks of rivers, farms, field plots, towns, and other features in the North Dakotan and Minnesotan landscape.

The robotics study proved that experiential education enhanced the social and academic development of the middle school students by encouraging social interaction and cooperative learning (Nugent, Barker, Grandgenett, & Adamchuk, 2010). It allowed hands-on, mind-on, self-directed learning to help the students develop analytical and problem-solving skills.

This study used a two-group design to address the following questions:

1. What is the impact of an intensive weeklong robotics/geospatial technologies summer camp on STEM learning and attitudes?
    a. The group was compared to a control group who did not receive the STEM intervention

2. What is the impact of a three-hour (short-term) session on STEM learning and attitudes?
    a. Held pre- and post-learning and attitude surveys.

(Nugent et al., 2010).

The University faculty and students held a short introductory lecture followed by hands-on activities supported with worksheets (Nugent et al., 2010).

The students worked in pairs, and more advanced challenges required small groups of three or four students. Similar to our study, students learn to collaborate and communicate ideas with their peers. This was another study that based their evaluation on a five-point scale, ranging from strongly disagree (1) to strongly agree (5). They focused on the motivation and effectiveness of the learning strategies.

The students rated one question: "I am certain that I can build a LEGO robot by the following design instructions" (Nugent et al., 2010). This type of inquiry can be applied to our own balloon payload competition, valuing their confidence and understanding of STEM concepts. In the motivation section, the students also answered questions regarding how they perceived the value of math, science, GPS technologies, and robotics. They rated their interest in particular tasks and acknowledged how they felt regarding importance and usefulness. This section is important to the survey because research has shown that an early interest in STEM topics, especially in the middle school ages, is a good predictor for future learning or career interests (Nugent et al., 2010).

Overall, students' attitudes increased towards science, robotics, GPS and math (Nugent et al., 2010). Their self-efficacy, or belief they can complete tasks themselves, of using technology increased as well. The students in the short-term study were highly engaged and motivated, due to the limited cognitive load. They increased their self-reported problem-solving skills and teamwork. (Nugent et al., 2010).

An Engineering Design Project, or the Mousetrap Car Experiment, tested the effectiveness between using physical and virtual materials as instructional tools in a hands-on engineering design project for 56 middle school students (Klahr, Triona, & Williams, 2006). Seventh and eighth-grade students designed mousetrap cars and tested how far they could propel them. Working in "discovery mode," the children devised an optimal design that would propel the cars dozens of feet (Klahr et al., 2006). The students learned STEM concepts such as the conservation of energy, torque, friction, and mechanical designs. Focusing on the exciting challenge of propelling the cars, the students intuitively developed an understanding for the underlying physical laws (Klahr et al., 2006).

The children took a pre- and post-survey before performing any of the virtual or physical car-building activities. The virtual test included using a computer program that would virtualize the assembly and testing of the mousetrap car. The students clicked on one of the sections for each part of the car, aiming to design the most effective design. The knowledge assessment questionnaire asked them "which body length, back axle width, back wheel size, back wheel thickness, front wheel size, and front wheel thickness would make a car travel farther, or whether that factor had no effect" (Klahr et al., 2006, p. 191). The pre-survey asked the students if they had any previous experience with constructing similar car designs. An open-ended question was included in the post-survey, asking the students to name any other parts they could think of, not provided by the study, that would improve the outcome (Klahr et al., 2006). Students that were considered "good responders" provided answers such as: "Make sure the car goes straight; let the string come loose from the axle after it fully unwinds so the car can free roll; or make sure the surface of the floor is smooth" (Klahr et al., 2006).

The children completed their car design much faster in the virtual than the physical condition (Klahr et al., 2006). But overall, the students benefited from the physical, hands-on approach. Both their pre- and post-survey scores for the physical scenario were higher when dealing with the tangible models.

Past Student Balloon Programs

Near-space ballooning has become an increasingly popular activity used to educate students of all ages about STEM concepts. Ballooning is a relatively low-cost way to reach the near-space environment; sending payloads up to 31 km. altitude By using an engineering design method, students are able to engage in these hands-on, exciting projects. They are exposed to such opportunities, which may influence their career choices in STEM later on in their academic career.

One balloon program at Taylor University in Indiana, called the High Altitude Research Platform (HARP), provides introductory astronomy classes with invigorating STEM lessons. They have teams of five to six students that create an experiment and then launch it into the stratosphere.

The HARP balloon experiment helped students:

1. Learn the scientific method (hypothesize, test, observe, interpret, document)
2. Learn hands-on technical skills (design, fabrication, electronics, team work)
3. Learn engineering principles (heat transfer, sensors, GPS, data processing)

4. Learn about atmospheric structure (pressure, temperature, stratosphere, wind)
5. Gain physics knowledge (acceleration, radiation)
6. Apply data analysis skills (Excel, plotting profiles, handling noisy data)
7. Produce a document of the end-results (team report, presentation)

(Voss, Dailey, & Snyder, 2011).

The HARP project was able to evaluate their students over two full years (four semesters). This thesis study does not have as much time with the middle school students as Taylor University. The professors at Taylor University applied pre- and post-survey assessments, which analyzed the best teaching strategies. Such educational assessments consisted of intrinsic motivation, application knowledge, and cognitive skills (Voss, Dailey, & Snyder, 2011).

Outreach has been a significant portion of the 52 NASA Space Grant Programs. Another study performed by Arizona State University (ASU) evaluated the efficiency of utilizing the students of NASA Space Grant to spread STEM education. There are fewer graduate and undergraduate STEM students in present day universities (Klug et al., 2006). It is up to these college students to reach out to the next generation of students.

Certain professors and students are able to teach basic STEM concepts to younger students more effectively than others (Klug et al., 2006). Unique methodologies and forms of outreach are better candidates for different groups of students. Lessons learned from each proto-type program can be exported to other Space Grant Programs (Klug et al., 2006). The Arizona Space Grant has their graduate students attend an ASU/NASA

Outreach Introduction seminar and a K-16 educator conference. Students are able to see STEM presenters and presentation styles (Klug et al, 2006). The students then participated in Space Grant Balloon Launches, a form of service to the community and a source of inspiration for younger students. Through comments and reports, the graduate students were highly enthusiastic and encouraged at their ability and interest in participating in STEM outreach (Klug et al., 2006). In summary, programs like this are models for other Space Grant Programs. They can be produced and disseminated for replication around the United States (Klug et al., 2006).

The Oregon Institute of Technology's (OIT) balloon program (LaunchOIT) has collaborated with local Ferguson Elementary School to establish an effective and educational balloon project, called "to the Edge of Space" (Kansaku, 2007). This alliance, formed in 2004, allows elementary students to develop experiment payloads. Using math and science concepts learned throughout the year, they investigate temperature, pressure, ozone, and visible light (Kansaku, 2007).

To begin, LaunchOIT faculty presented a PowerPoint lesson to the class, explaining the project. The students were left to design their own payload, working in teams. Using their inquiry-skills, they made sure the interior of their payload design would not freeze. They placed a vial of glass inside their design and placed the payload in the freezer. If the vial did not freeze, then their design was successful.

At the time of launch, the balloon team filled a latex balloon with helium. An amateur radio transmitter was coupled to a GPS receiver, formatting the information into Automatic Packet/Position Reporting System (APRS®) packets (Kansaku, 2007). The mapping software that APRSPoint uses is Microsoft MapPoint, the same tracking software that the VMS launch utilized.

Students were extremely excited and enjoyed participating in this invigorating activity. The fifth graders who graduated into sixth grade came back to present their PowerPoint presentation at the fall parent meeting (of the current fifth grade students) (Kansaku, 2007). During this presentation, Kansaku reported "the teacher heard science concepts that had been remembered by the sixth graders for a year without having been reviewed" (2007). The hands-on approach positively impacted the student's ability to learn STEM materials, proving the regular "fire and forget" method is less influential.

After the launch, the elementary students took a field trip to the OIT campus, having lunch, participating in interactive presentations, and touring the alternative energy labs (Kansaku, 2007). College students were able to present their undergraduate research activities, a great opportunity for the elementary school children. The students were exposed to a college campus, instructors, and students. This was a great opportunity, because they may not have had such an experience until much later in their lives.

"To the Edge of Space" was so successful that they extended the outreach activity to the high school level. Because this is a non-major science and technology course, any high school student could join this multidisciplinary activity. Critical STEM knowledge was gained through both in-class and fieldwork lessons, with the help of former students, teachers, and parents (Kansaku, 2007).

STEM in the United States

School districts are bound by the No Child Left Behind Act of 2001 (NCLB), set by President George W. Bush (Sirinterlikci, Zane, & Sirinterlikci, 2009). NCLB reauthorized the Elementary and Secondary Education Act of 1965 (P21, 2013). This 1965 Act identifies English, reading or language arts; mathematics; science; foreign languages; civics; government; economics; arts; history; and geography as the core subjects (P21, 2013). Approaching STEM education with this teaching method places science secondary to math and reading. With NCLB, state-level National Assessment of Educational Progress (NAEP) scores would now serve as a common measure across states (Mathis, 2010).

The classroom teacher has limited class time to expose students to all types of science experiences. This lack of exposure may decrease the amount of STEM leaders produced by this generation. With NCLB, most of the teacher's time is spent on test preparation and test proctoring. A narrow set of scientific facts is provided as the testing material, since the teachers are required to "teach to the test" (Marx & Harris, 2006). Many elementary and middle school administrators are reluctant to allow time for a daily instruction of science.

School districts – teachers in particular – are pressured to meet the curriculum guidelines, despite President Barack Obama's *Educate to Innovate* Campaign. His mandate declared STEM education to be a high priority throughout the next decade (Sirinterlikci, Zane, & Sirinterlikci, 2009). The national goal, set in 2009, requires more attention to scientific inquiry and technological innovation than the previous presidencies. He designated $260 million in public and private investments to move American students from "the middle to the top of the pack in science and math" (The White House, 2009). In addition, Obama's $4.35 billion "Race to the Top" school grant fund provides an advantage to states that commit to improving their STEM education. Results from these motives would reaffirm and strengthen America's role as the world's engine of scientific discovery and technological innovation (The White House, 2009).

On February 9, 2012, President Obama provided NCLB waivers to eleven states that volunteered to raise their education standards: Colorado, Florida, Georgia, Indiana, Kentucky, Massachusetts, Minnesota, New Jersey, Oklahoma, New Mexico and Tennessee (NSTA, 2012). The states need to submit a request for a waiver if they want to be approved. This waiver will provide more flexibility to the state, allowing them to disregard previous NCLB standards and administer their own higher education reform. As of May 20, 2013, the Obama Administration has approved 37 out of 45 waiver requests (U.S. Department of Education, 2013).

Under the Obama Administration, congress raised the national education budget to $69.8 billion, which went into effect on October 1, 2012 (NSTA, 2012). They aim to eliminate the Mathematics and Science Partnerships program and replace it with the $150 million Effective Teaching and Learning: STEM (NSTA, 2012). They also requested $80 million to prepare 10,000 STEM teachers by including teacher and leadership training and professional development over the next decade.

The Obama Administration has also allocated $2.5 billion in funds to align state curricula with the NGA/CCSSO standards (Mathis, 2010). There are additional funds for "turn-around" strategies for schools that fail to produce adequate standards-based results (Mathis, 2010). These include "firing the principal, firing some or most of the staff, and converting the school to a charter school or closing the school(s)" (Mathis, 2010).

Ultimately, the federal government has the final say in the curriculum, pedagogy, and structure of the nation's schools.

Common Core State Initiatives

The Common Core State Standards Initiative, released in 2010, is a nationwide effort, implemented by 48 states, 2 territories, and the District of Columbia (www.corestandards.org, 2012). Led by the National Governors Association (NGA) Center and the Council of Chief State School Officers (CCSSO), this initiative will focus on what knowledge and skills K-12 students should acquire before graduating high school (Porter, 2011). Also in partnership with the NGA Center and CCSSO are Achieve, Inc., ACT, and the College Board (NGA, 2009). These common core standards are "necessary for national economic competitiveness in a global economy" (Mathis, 2010). The NGA/CCSSO collaborative efforts that have a clear intention of adopting uniform standards, which are therefore most likely to become the national curriculum standard (Mathis, 2010).

The purpose of the Common Core Standards is to have uniform pedagogy standards that all states can voluntarily adopt, while concurrently including any additional standards, as long as Common Core Standards represent 85 percent of the mathematics and English language arts standards (NGA, 2009).

There is a desperate urgency to develop and adopt a common set of standards among the U.S. Department of Education (USDE), even if they are not directly involved with the creation of the standards (Porter, 2011). The USDE grants awards in President Obama's Race to the Top competition, putting considerable resources behind state adoption and use of the standards (Porter, 2011).

Next Generation Science Standards

A new education framework, finalized in 2013 by the National Research Council (NRC), lays outs disciplinary core ideas, science and engineering practices, and crosscutting concepts that students in K-12 should master in preparation for college and future careers (NGSS, 2013). These new standards promote critical thinking and communication skills essential for students' success. Students will develop habits and skills that scientists and engineers use, improving their cognitive, social, and physical learning skills (NGSS, 2013). NGSS aims to advance the country from the15-year-old preexisting standards – National Science Education Standards (NSES) and Benchmarks for Science Literacy from the American Association for the Advancement of Science (AAAS) – to the modern day Next Generation Science Standards.

The VMS project is based off the workshops with this new outlook: hands-on design, construction, and launch processes that require critical thinking skills, in and out of the classroom.

The Partnership for 21st Century Skills

The Partnership for 21^{st} Century Skills (P21) is a national organization that advocates for every American student to receive twenty-first century readiness, providing tools and resources to help the U.S. education system remain innovative (P21, 2014). They strive to fuse content and the four C's: critical thinking and problem solving, communication, collaboration, and creativity and innovation (P21, 2014). Every child in America needs twenty-first century knowledge, especially because 65 percent of today's grade school kids will have a job that is not even created yet (U.S. Department of Labor, 2013). P21 believes there is a profound gap between the knowledge and skills obtained in grade school and the knowledge and skills needed for the twenty-first century communities and workplaces (P21, 2013).

The framework for the *Learning in the 21st Century* consists of six main elements. They cover all the essential skills that students will need to succeed as citizens and employees throughout the twenty-first century. They cover:

1. Core Subjects (English, reading or language arts; mathematics; science; foreign languages; civics; government; economics; arts; history; and geography)
2. 21st Century Content (Global Awareness; Financial, economic, business and entrepreneurial literacy; Civic literacy; Health and wellness awareness; Environmental literacy)
3. Learning and Thinking Skills (Critical Thinking and Problem Solving Skills; Communication Skills; Creativity and Innovation Skills; Collaboration Skills; Information and Media Literacy Skills; Contextual Learning Skills)
4. ICT Literacy (ability to use technology to develop twenty-first century knowledge and skills)
5. Life Skills (Leadership; Ethics; Accountability; Adaptability; Personal Productivity; Personal Responsibility; People Skills; Self Direction; Social Responsibility)

6. 21st Century Assessments (Standardized testing alone can only measure a few important life skills. Balancing standardized assessments and effective classroom assessments help students master critical content and skills) (P21, 2013).

Are There Enough STEM Jobs in the U.S. Workforce?

The United States is clearly falling behind other countries in the capacity for scientific discovery, innovation, and economic development (Freidman, 2005). The primary solution is to jump-start the K-12 educational system and prepare the future generations in fields such as science, technology, and engineering. But there's another aspect to consider: are there enough technological and scientific jobs in the U.S. to support the incoming surge of STEM students? Is the U.S. producing too many scientists for the workforce to absorb?

Some experts believe America is currently performing adequately, but will decline in global academic standings in the future. Dr. Shirley Ann Jackson is a physicist who has been president of the American Association for the Advancement of Science in 2005 and president of Rensselaer Polytechnic Institute since 1999. In 2009, President Barack Obama appointed Dr. Jackson to serve on the President's Council of Advisors on Science and Technology (RPI, 2013). Dr. Jackson admits:

> "The U.S. is still the leading engine for innovation in the world. It has the best graduate programs, the best scientific infrastructure, and the capital markets to exploit it. But there is a quiet crisis in U.S. science and technology that

> we have to wake up to. The U.S. today is in a truly global environment, and those competitor countries are not only wide-awake, they are running a marathon while we are running sprints. If left unchecked, this could challenge our preeminence and capacity to innovate" (RPI, 253).

As the National Science Board said, "the number of jobs requiring science and engineering skills in the U.S. labor force is growing almost 5 percent per year. In comparison, the rest of the labor force is growing at just over 1 percent" (Freidman, 258). By the time these scientists finish their extensive schooling, they need to acquire a job where they can practice their skills. Only 25 percent of the American PhDs will ever land a faculty position in the U.S. scientific labor market. Even fewer, 15 percent, will land a position in a research university (Benderly, 2010).

American universities are dealing with a difficult situation with their departmental positions. Competition for science faculty jobs is in such high demand that hundreds of qualified applicants pursue every advertised opening at universities and research labs (Benderly, 2010). Science graduates need to land a position at these universities or research institutions in order to compete for federal grant funds. When there are limited professorships, departments will hire more graduate and post-doctoral students. This provides inexpensive labor and the research will still be completed. Doctoral-level researchers in America receive around $40,000 a year for 40-80 hours per week with no job security (Benderly, 2010). This forms an abundance of post-doc students, allowing the faculty professors to have a better chance of winning grant renewals, more publications, and more skilled hands at their disposal.

Other competitive countries have a permanent way of staffing their science labs; whereas in America, research labs and university departments fund graduate students, post-docs, and non-tenured staff with short yearly intervals. This has both positive and negative repercussions. The advantages of staffing labs with temporary employment include:

- The institutions find the brightest and finest talent for projects that meet national priorities set by funding agencies or congress.
- There is flexibility in choosing studies and researchers, especially when there is rapid change in direction. Research grants are designed for specific purposes and last a limited number of years.
- It frees the government from owning its own labs and managing staff. (Benderly, 2010)

The disadvantages of staffing labs with temporary employment include:

- Funding for labs is never guaranteed.
- They are dependent on winning recurring grants – individual careers are at the mercy of annual competitions.
- In times of tight federal budgets, many labs are forced to shut down.
- Young researchers lack stable opportunities to start their own careers.

- This discourages students from pursuing professional careers in science, which may ultimately hurt the United States.

(Benderly, 2010)

By the 1970's, the number of post-doc students alarmingly increased and they spent a considerable amount of time as "trainees". Unfortunately, this buildup continued for three decades (Benderly, 2010). Five or more years of post-doc training has become the norm, while the percentage of PhDs who land academic positions rapidly drops. This is the main problem at the end of the education pipeline.

Benderly comments, "The average age of young scientists who do actually land faculty jobs by winning their first competitive grant has risen to 42. Scientists of previous generations, such as Albert Einstein, Marshal Nirenberg, and Thomas Cech, were winning their Nobel Prizes for work done in their twenties" (2010).

Foreign Talent

There are a lack of applicants for the lower-income academic positions, such as lab assistants and graduate students. University professors may select foreign talent for these availabilities, who are essential for the professor's research to be completed. These positions may be the only way for foreign-born students to enter the U.S. job market.

The National Science Board discovered that foreign-born students accounted for over 14 percent of all Science and Engineering (S&E) occupations in 1990 (Freidman, 259). Between 1990 and 2000, the proportion of foreign-born students in S&E occupations rose significantly:

- Bachelor's degrees rose from 11 to 17 percent
- Master's degrees rose from 19 to 29 percent
- PhDs rose from 24 to 38 percent

(Freidman, 259).

Students in Beijing, China, have the opportunity to work at the Microsoft Research Asia (MSRA). They "view this as a once-in-a-lifetime opportunity. They voluntarily work fifteen to eighteen hours a day and come in on weekends. They work through holidays… if you go in at two A.M. it is full, and at eight A.M. it is full" (Freidman, 267). This is the "sort of inspired leadership in science and engineering education [that] is now missing in the United States" (Freidman, 268).

CHAPTER III

NEAR-SPACE BALLOONING AT UND

A Brief History

In 1998, Space Studies lecturers at the University of North Dakota, John Graham and John Nordlie, established the first student platform that would fly experiments into the stratosphere (Livingston, 2007). Their goal was to “create access to ‘near-space’ for student spacecraft and engineering projects” (Livingston, 2007).

Graham and Nordlie contacted ballooning groups from across the country, gaining first-hand information about how to create a successful ballooning program. Their Federal Aviation Administration (FAA) liaison, George Kelley, provided a copy of the US Federal Aviation Regulations (FAR) Part 101, specific to moored balloons, kites, unmanned rockets and most importantly, unmanned free balloons (Nordlie, 1998).

For their first launch, they obtained a tank of compressed Helium, set up a filling system, and connected their payload to a 1200-gram balloon. The gondola was created from a Styrofoam container. Styrofoam is lightweight, durable, insulates well, cheap and will protect the experiments upon impact. It was important to utilize lithium batteries, for these have a higher tolerance and lifespan in such cold temperatures. Also, they have the highest energy to weight ratio of affordable batteries (Nordlie, 1998).

Even though students had busy schedules, the original ballooning group received students from various disciplines. All students were welcome to participate. They received students from engineering, computer science, space studies, other technology-based majors and non-STEM subjects such as public relations (Nordlie, 1998).

The first mission consisted of Nordlie, Graham, amateur radio operators, and expert geocaching individuals. The first payload was not recovered, although many lessons were learned, ultimately impacting the future and longevity of the program.

The VMS NSB Project was the first occasion when NDSGC launched two balloons simultaneously. This accomplishment required duplicate tracking gear and filling equipment (Table 1), additional student helpers, and the chase team had to perfect their methods of successfully locating each balloon.

Permissions for Ballooning

Local launches out of Kempton, North Dakota have permitted student research to reach the near-space environment, in correspondence of the Space Studies Department and the North Dakota Space Grant Consortium. It is imperative to maintain a safe and respectable ballooning program at the University of North Dakota. There are regulations from the Federal Communications Commission (FCC) and the Federal Aviation Association (FAA) that govern near-space balloon launches.

The Federal Communications Commission (FCC). While launching a balloon, there are many situations that could cause harm to the launch team, persons on the ground, and pilots in the air. Most of these hazards have preventative steps that the ballooning team needs to follow.

The FCC regulates the use of Amateur Radios, tracking systems that NDSGC uses to locate the balloons. There needs to be at least one licensed HAM Radio operator at a balloon launch, who will safely lead the balloon chase.

There are three different license classes, Technician License, General License, and Amateur Extra License class (AARL, http://www.arrl.org/ham-radio-licenses). NSB launches only require possession of a Technician license. The VMS thesis launch had three licensed HAM radio operators: Marissa Saad (KD0RMG), Dr. Ron Fevig (NC0UCV), and graduate student Brian Badders (KD0TPR).

The Federal Aviation Administration (FAA). A crucial step to prevent any major ballooning disasters is coordinating and cooperating with the FAA. Any balloon impact with an aircraft would create potential accidents and mission failures. Therefore, the FAA administers a specific set of rules; listed in the FAR 101, subpart D. If any ballooning mission meets certain qualifications, the launch team does not need to obtain a waiver or alert the FAA of said launch.

A Flight Service Station (FSS) assists with navigational aid to pilots. They are responsible for flight planning, weather, Pilot Reports (PIREPS), and Notice to Airmen (NOTAM) reports.

Near-space ballooning falls under the exempt category in the FAR 101, and a NOTAM does not need to be filed if specific requirements are met:

1. Total payload chain weight does not exceed 12 pounds.
2. Any single payload with a surface density exceeding three ounces per square inch on any surface does not exceed four pounds.
3. Any payload does not exceed six pounds.

4. Uses a rope that separates the suspended payloads from the balloon at no more than 50 pounds of force.

The FAA mandates that a balloon's launch site must lie five miles away from any airport. Additionally, the first 1,000 feet of ascent cannot be situated over a populated area and the visible sky must have less than 50 percent cloud cover to ensure the safety of pilots. It is essential to launch with low atmospheric wind speeds, thus, early morning launches are favored – before the Sun has time to heat up the Earth's surface and produce relatively strong winds.

Because ground level atmospheric pressure is unique in different locations, sea level pressure is used as an international reference for atmospheric pressure for all commercial flights. To help prevent in-air collisions, atmospheric pressures are broken into flight levels, which are pressures translated into altitudes in steps of one hundred feet. Flight levels are denoted as "FL" plus the altitude in feet divided by one hundred. (Flightplan, 2014). This way, all aircraft report their flight level instead of the actual altitude, avoiding collisions (SKYbrary, 2013*)*. For example, a balloon located at 60,000 feet is denoted as "FL600". When preparing for a balloon mission, the FSS should be notified that the balloon's route is "ground to FL600".

The VMS dual-balloon launch followed all of the legal requirements and issued a NOTAM. The team filed a NOTAM to the Air Traffic Controller (ATC) at Grand Forks International Airport, Grand Forks Air Force Base and notified the University of North Dakota's flight safety office. It is always best to inform the FAA out of courtesy, even if a mission qualifies as an exempt status launch.

The VMS NSB launch gained FAA clearance with the following information:

1. Location in relation to nearest public-use airport: 4.7 Nautical Miles bearing 110 degrees East South East of Grand Forks International Airport (GFK)
2. Time of operation reported: 0830-1300 (local military time). Because the FSS requests Zulu time, the final time that was reported to FAA was 1330-1800 Zulu.

The final NOTAM clearance number was 11080 GFK. Finally, it is imperative to call and cancel the NOTAM once all NSBs are safely on the ground. Usually NOTAMs do not need to be cancelled, but when planning ballooning missions, the exact launch time is undefined and a time range is given to the FAA. Many factors affect when the balloon will be launched, such as weather, human delays, and technical problems. The FAA needs to have a specific end time to add to their reports.

The launch team also reported to the flight safety office at the University of North Dakota, specifically the Supervisor of Flight (SOF) of Flight Operations. As required by the SOF, the team needed to call a few days ahead of the expected launch, to provide the SOF ample time to prepare. Prior to liftoff, the flight team was required to call one hour before the launch. Last, the team was required to call again once the balloons were safely on the ground. Air Traffic Control-trained Aerospace graduate student, Marian Courtney, performed all of the FAA-related preparations for the VMS launch.

Facilitating STEM Education

The ballooning program at UND utilizes a vast range of latex balloons, ranging from 350 grams to 3000 grams in mass. NSBs are significantly cheaper than launching experiments onboard a high-powered rocket; and are able to transport combinations of different science subjects concurrently. The largest balloon ever flown at UND was a 3000-gram balloon by the electrical engineering team, using three tanks of compressed helium (Livingston, 2007). Every year, NDSGC aims to advance their efforts in STEM education, expanding on their programs, contacts, and launch methods.

NDSGC provides many STEM outreach opportunities for middle and high school students across the state of North Dakota. The Near-Space Balloon Competition (NSBC) is an annual student payload competition, beginning in November and concluding in May. Students submit proposals for a science experiment designed to fly up to 100,000 feet in altitude, well into the stratosphere. Post-launch, the students complete a science report that is submitted for evaluation and a chance to win first, second, or third place. Qualifying teams gain first hand experience working a STEM project. The students develop a mission plan and progress through the scientific process just like a space scientist or engineer. The author had been the co-coordinator and lead mission director for the 2012 NSBC and the head coordinator and mission director for the 2013 NSBC.

The Near-Space Environment

The near-space environment of Earth's atmosphere is classified as the region above 60,000 feet and below 328,000 feet (Kaiser, 2013). Experiments in near-space experience effects more closely resemble the space environment than surface effects. Air pressure at this altitude is only 1 percent that of the surface, cosmic radiation is over 100 times that of sea level, and air temperatures can drop to -60 degrees Fahrenheit or colder (Kaiser, 2013). The ozone layer is situated within this region, resulting in strong ultraviolet radiation.

Balloons travel through and study an intricate layer of the Earth's atmosphere. With helium-filled NSBs, students can say they have "touched space". The images and videos returned to the students are remarkable teaching tools. The students will see the curvature of the Earth and the dark, black background that is the void of space. They will be able to see the thin, blue, fragile atmosphere that protects and sustains all life on Earth. Taking the curriculum into near-space is a once-in-a-lifetime activity that inspires, teaches, and excites the younger student generation.

Materials

NDSGC funded and supplied the following materials for their ballooning program. NDSGC has doubled the filling, launch, and tracking systems to support such a developing balloon program (Table 1). The materials are organized into 3 categories: (1) materials required to prepare the launch, (2) materials needed for the payloads, and (3) materials that ride onboard the payload train during flight.

Table 1: Materials Used for the NSB Project

	Quantity	Location
Launch Prep System		
HARRIS 0-200 PSI regulator	1	http://www.grainger.com/product/HARRIS-Heavy-Duty-ArgonNitrogenHelium-Regulator-5KZ47?Pid=search
Filling Hose	1	Menards
Gallon of water	2	Menards
Tarp	2	Donated
Compressed 200 ft^3 Helium Tanks	6	AirGas
Reflective Rope, max 50lbs	4	http://www.walmart.com/ip/SecureLine-5-32-x-50-Yellow-Visiflect-Reflective-Rope/24093493
Parachutes	2	Donated, NDSGC rocketry program
Walkie-Talkies (for balloon chase vehicles)	10	Menards
Payload Materials		
GoPro Naked Camera	1	Discontinued, www.gopro.com
Canon Powershot S70 Digital Camera	1	Donated NDSGC
Canon Powershot S70 Digital Infrared Camera	1	Donated NDSGC
Styrofoam boards	6	Menards
Duct Tape	3	Menards
Hot Glue Gun/Extra Glue	2	Menards
Box Cutter Knives	2	Menards
Clear tubing	3	Menards
*NeuLog™ Temperature Sensor	1	http://www.neulog.com/TemperatureloggerSensor.php
*NeuLog™ Wide-Range Temperature Sensor	1	http://www.neulog.com/Widerangetemperatureloggersensor.php
*NeuLog™ UVB Sensor	1	http://www.neulog.com/UVBloggersensor.php
*NeuLog™ Pressure Sensor	1	http://www.neulog.com/Pressureloggersensor.php
*NeuLog™ Magnetic Field Sensor	1	http://www.neulog.com/Magneticloggersensor.php
*NeuLog™ Carbon Dioxide Sensor	1	http://www.neulog.com/COsub2subloggersensor.php
*NeuLog™ Oxygen Sensor	1	http://www.neulog.com/Oxygenloggersensor.php
*NeuLog™ Acceleration Sensor	2	http://www.neulog.com/Accelerationloggersensor.php

(Table 1 Continued)	Quantity	Location
Payload Materials		
*NeuLog™ Humidity Sensor	1	http://www.neulog.com/Relativehumidityloggersensor.php
*NeuLog™ Battery	10	http://www.neulog.com/BatterymoduleBAT200.php
*NeuLog™ USB Bridge Module	1	http://www.neulog.com/USBmoduleUSB200.php
Balloon-Based Systems		
1500 Gram Kaymont Latex Balloons	2	http://kaymontballoons.com/Near_Space_Photography.html
SPOT Tracker	1	http://www.findmespot.com/en/index.php?cid=101
*SPOT Tracker	1	http://www.findmespot.com/en/index.php?cid=102
Kenwood D700 Transceiver	1	http://www.kenwoodusa.com/Communications/Amateur_Radio/Amateur_Radio_Retired/TM-D700A
*Kenwood D710 Transceiver	1	http://www.kenwoodusa.com/communications/amateur_radio/mobiles/tm-d710a
*Handheld Kenwood TH-D72A Transceiver	2	http://www.kenwoodusa.com/Communications/Amateur_Radio/Portables/TH-D72A

* = New, duplicated materials obtained in 2013 for the VMS thesis dual-balloon launch. These duplicated tracking systems and payload experiments will be utilized for future dual-balloon NSBC launches and Grand Forks Public School launches.

CHAPTER IV

METHODOLOGY

Justification For Research

An extensive number of hands-on STEM activities have been provided for middle school students across the nation, as mentioned in the literature review. Few have involved ballooning activities, specifically targeting the middle school age range. Previous knowledge of how to design and construct a payload from past Space Studies Department and NDSGC balloon launches inspired the procedure of the VMS project.

Near-space balloon missions will only function with the appropriate materials and technical expertise, qualities that the Space Studies department and NDSGC possessed. Ballooning-related teaching opportunities are rare for the average teacher, who may not have the time and knowledge of how to launch a near-space mission.

It was imperative to immediately reach out to the public schools in North Dakota and offer the unique learning experience through ballooning. This occurred during the 2012 school year with multiple teachers from different school districts. The 7^{th}-grade class from the West Fargo STEM School was the most promising candidate for the ballooning collaboration, but the mission was cancelled due to weather and ultimately time commitments.

Institutional Review Board

Federal regulations state that if a research subject is a minor under the age of 18, special precautions must be implemented in order to protect the subject. The IRB paperwork required to gain permission can be quite substantial and can take months to be approved, because the UND IRB convenes only once a month. All forms, documents, and materials must be submitted to the IRB before they are approved.

The appropriate UND IRB paperwork was filed and underwent processing in May of 2013. An online educational module was completed, registering under the IRB Social/Behavioral Researcher unit of UND. She received final approval on October 24, 2013. The Basic Course approval number was 10318365. The final hard copy document was received on October 29, 2013.

Pre- and Post Surveys

The pre- and post-surveys were devices that would quantitatively analyze the effectiveness of the NSB project. The eighth graders anonymously completed these surveys. The pre-survey was correlated to the post-survey by the demographic information that the students provided in the first section of the document. The third group of questions was asked using a Likert Scale format. They had five options: Strongly Disagree, Disagree, Neutral, Agree, and Strongly Agree.

In order to evaluate the Likert-scale questions, the phrases were given a value of one to five, *Strongly Disagree* as 1 and *Strongly Agree* as 5. This way, the calculations were computed accurately, using numerical values. Most questions were worded positively; meaning *Strongly Agree* would represent an affirmative response. In order to avoid students blindly answering to one side of the spectrum, negatively worded questions were mixed into the survey to increase validity.

Not all of the students responded to every survey question. Some students accidentally skipped them or intentionally did not participate. The students, as instructed in the assent form, were not forced to answer anything they did not want to since the surveys were voluntary.

The total number of student participants (n value) who completed each survey question varied. Therefore, the weighted average was used so that each survey question was averaged proportionally to the value it represented, expressed as $\bar{\chi}$. The weightings determine the relative significance of multiple categories in relationship to each total number of participants. To produce the weighted averages, the following steps were administered for the pre-survey and post-survey data:

$$\bar{\chi} = \frac{\omega_1 x_1 + \omega_2 x_2 + \cdots + \omega_n x_n}{\omega_1 + \omega_2 + \ldots + \omega_n}$$

Each survey response across the spectrum of *Strongly Disagree* to *Strongly Agree* is represented with a numerical value of 1 to 5. For each survey question, responses to each of the five Likert values were tallied (x_n) and multiplied by the corresponding weight (Likert scale value, ω_n). The products are all added together and then divided by the total number of participants for that particular survey question, seen in the denominator.

In order to determine if the change in $\bar{\chi}$ between the pre- and post-survey was statistically significant, the following Student's t-Test was implemented:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{s_{\bar{X}_1 - \bar{X}_2}}, \text{ where } s_{\bar{X}_1 - \bar{X}_2} = \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}$$

(Handbook for Biological Statistics, 2010)

A Student's t-Test compares the means of two categories of data. The Welch-Satterthwaite t-Test was the specific type of Student's t-Test used in this study. The

Welch's t-Test compares two independent samples from the pre- and post- survey populations that also have unequal variances (Handbook for Biological Studies, 2010).

The first and second sample sizes, $n_1$and n_2 are each drawn from a population size with a mean of $\bar{X}_1$and $\bar{X}_2$ and variance $s_1^2$and s_2^2, respectively (Arnold, 2014).

In Microsoft Excel, these calculations can be performed with the Welch's TTEST function for unequal variances: "=TTEST (array1, array2, tails, type)". The distinguishing difference between Welch's t-Test and the equal measurements t-Test is entering "3" for "type" instead of a "2" (Handbook for Biological Statistics, 2010). The "3" computes a calculation with two series with unequal standard deviations, whereas a "2" computes two series with equal standard deviations (OpenWetWare, 2010).

Excel's TTEST function returns p, which is the probability that the null hypothesis ("the NSB project did not influence the students") is correct. Since a 95% confidence interval was selected for this experiment, any p value greater than 5% (alpha) signifies that the results are due to random chance and then the null hypothesis is stated. For questions where the p value is less than 5%, the null hypothesis was rejected.

Contacting Valley Middle School

The NDSGC and the Space Studies Department at UND conduct numerous STEM outreach activities and are continuously pursuing new collaborations. It was after the NSBC launches that a balloon-based learning activity with an entire grade from a single school was pursued. Over the summer of 2013, Valley Middle School of Grand Forks Public School System was contacted: assistant superintendent of Teaching and Learning, Mr. Jody Thompson, VMS Principal, Mr. Barry Lentz, and eighth-grade Earth

Science teacher, Mr. Brent Newman. Newman was very enthusiastic about integrating a ballooning activity into his astronomy and meteorology unit during science class.

A web-conference was held in August of 2013 with Dr. Ron Fevig, of the Space Studies Department; Dr. Gail Ingwalson, of the Education department; and Caitlin Nolby, the NDSGC Coordinator. It was here that both UND and VMS solidified their interest in the proposed collaboration. General details were discussed, such as approximate dates, curriculum plans, and important Institutional Review Board (IRB) deadlines.

For the next two months, communication was completed via email. Newman was presented with the NeuLog Data Sensors website (Appendix E), where he selected his desired sensors that would mirror the material that the students had already learned. The final ten sensors were provided by NDSGC and distributed among the classes (Figure 2, page 45).

Presentation/Introduction Workshop

Before initiating the presentation, an assent form and a pre-survey (n = 124) were distributed to all of the students. The pre-survey (Appendix E) would quantitatively assess the initial level of STEM interests the students had prior to the NSB project. This assessment tool recorded demographic information, prior STEM influences, and their current outlook on future High School STEM classes.

It was important to assess how many students grew up with building toys, such as Lincoln Logs, K'nex, and Lego's. Also, a key factor was analyzing how many students had a parent or guardian working in a STEM field. It was important to see how strong the students' bias' were.

It was imperative to let Newman conduct his classes with the same style and tempo as he normally would, in order to accurately analyze how a ballooning unit would fit into the actual middle school curriculum. Newman informed the students of the daily activities and was always in control of the classroom dynamics.

The introductory presentation took place on October 31, 2013 for all six classes. Additional spectators entered the room periodically throughout the day, including the principal, other eighth grade teachers, and school staff. Delivered via PowerPoint, the 20-minute presentation summarized everything the students would be doing for the next three weeks (Appendix F; Image 2). It covered:

- What is a near-space balloon?
- Why are these balloons useful? What can we study?
- Who uses balloons (Daily, periodically, and/or professionally)?
- How high and how far do balloons travel?
- Past images and videos of UND NSB missions

The students had all of the necessary information and expertise to participate in this project.

Payload Selection

The students selected their top three choices for their preferred payload (Table 2). Once they had selected their desired experiment, the students volunteered for payload roles. It was fascinating to see who quickly volunteered for each specific role. Commonly, the males raised their hands for the construction job. The females quickly chose most of the writing, PowerPoint-making, and final report roles.

A team leader was silently chosen for each team, especially in the early stages of selecting team roles. In 10 out of the 12 teams, observation showed females took the position. Some teams had one student assigning the roles and then asking if everyone agreed. Some teams "auctioned off" the jobs, cycling through the positions and asking, "Who wants this job?"

Table 2: Payload Selection

Payload Selection	
NeuLog Sensors	Temperature
	Wide Range Temperature
	Acceleration 1
	Acceleration 2
	Humidity
	Magnetic Field
	Carbon Dioxide
	Oxygen
	Pressure
	Ultraviolet B
Remote Sensing Imagery	Powershot S70 Canon Camera
	Infrared Powershot S70 Canon Camera
	GoPro Naked Video Camcorder (720p, 60fps)
Student proposals	Banana Experiment

The students had all of Monday, November 4, 2013 to solidify their payload design. Four of the classes had surpassed expectations and collaborated together fluidly. Not only did they finalize their payload design, they also finished the hypothesis and as much of the final report as possible.

Each NeuLog sensor was plugged into its own battery pack. The students took this into consideration while designing the size of their payloads.

Design Workshop

Newman created a worksheet on which the students stated their desired experiments, and most importantly, why they chose that experiment. He had previously covered the scientific process earlier in the school year, including the hypothesis, procedure, results, data analysis, and conclusion. The NSB project was a real-world example of how a team of space scientists and engineers would have to work together to produce research results. The students came to realize how important the design is to the overall success to the mission. The payload container had to house their selected sensor, giving it insulation, protection, and durability. They considered air resistance and drag, preparing the structure for the ascent and descent.

With no formal direction from instructors, the design team created the blueprint for their payload. They saw an example payload that the author brought to the introduction workshop (Appendix F; Image 3). They were given advice, such as to make sure the sensor *and* the battery fit inside. They were told to consider the function of the sensor: cameras would need a window to the outside whereas sensors such as acceleration would not.

Construction Workshop

The construction workshop took place on Tuesday, November 5, 2013. Newman had 6 consecutive science classes that began at 9:59 AM and concluded at 3:30 PM. Each class lasted 50 minutes. He began each class with a introduction about the construction process for the first 5 to 10 minutes. The teams that were falling behind in the design process received a longer introduction than the classes who were on schedule. It was here that Newman explained the importance of working with a team, whether it was with an orchestra, science group, or sports team. Using many different analogies, he conveyed the importance of preparation and working together. In a detailed metaphor, Newman articulated the importance of explaining how hours and hours of hard work at football practice is essential to prepare for “the big game”. The students could not slack off and solely play the games, just because “practice isn’t fun”. Additionally, he informed them that not everyone could play the role of the quarterback. This way, the students understood that not everyone could select the most popular payload activity, such as payload construction. Some students expressed disinterest about participating on the hypothesis or final report team. Newman informed them that every group would need a support team to provide the science and design plans. Not everyone enjoys the laborious, tedious preparation, but similar to scientists, commitment and teamwork is essential for a successful mission. Their team could not participate in a fun and exciting balloon launch if their payload had poorly developed science objectives.

It was up to the design team to create their payload shape and then monitor the construction team (Appendix F; Image 5). Only the design and construction team members were allowed in the science laboratory classroom, where the construction took place.

The hypothesis and final report team had the first day to research the full capabilities of their data logger. The students involved in the final report team watched the design and construction teams’ progress, taking pictures for their PowerPoint conclusion.

Newman’s style of teaching encourages the students to think of their own solutions. Some student groups were interested in launching a secondary experiment. One group asked to launch a chocolate bar. When Newman asked them what kind of data they hoped to receive, they lacked a scientific answer. This student group only supplied, “because it would be cool” as a response. He told them that until they researched the science they wanted to pursue and gave him their hypothesis, they were unable to launch this experiment. Another student group wanted to launch a banana (Appendix D). They provided a thorough response, proposing that they want to observe the effects the stratosphere and solar radiation had upon the banana. They had some prior knowledge of bananas turning dark and “mushy” that sparked their curiosity. Newman asked how they were going to quantitatively analyze the changes to the banana. They recalled one of Newman’s past lessons on variables and control groups. They decided to keep a control banana on the ground to use it as a comparison for the space banana.

The students worked well and handled the construction equipment with care. They respected the two sharp box cutters, dangerous tools that could have easily brought this activity from the classroom into the emergency room. It was quickly noted that when 115 eighth-grade students use Styrofoam, it is extremely messy.

When the class period for payload construction was over, none of the groups had finished. Most had all of their required Styrofoam panels cut out, which needed to be glued into place the following day. They had the option to come in the next day, either before or after school.

The teams that were closest to completion during construction day were those with less intricate shapes, such as small pyramids or cubes. The teams that had more complex cutting tasks, such as a “+” shape, pyramids on top of cubes, and other shapes with rounded corners took much longer for the construction team to finish.

Teams with more than one or two students participating in the construction process had overall slower progress. One team with four or five construction members decided to pass around the cutting blade, giving everyone a turn. Although teamwork is essential, this was not an effective method of time management. Their overall progress was significantly behind the other teams with fewer participants.

The teams with one design and one construction student worked much more efficiently. There was one team in period six that would have completely finished their payload, if technical problems didn't occur. The outlet hosting the hot glue gun had short-circuited between classes, and would not heat up the glue. These students experienced the unavoidable obstacles of a real science mission.

One innovative group decided to place the Styrofoam board on the ground vertically, instead of flat on the table (Appendix F; Image 6). They were able to cut much quicker, using gravity to assist the blade, cutting from top to bottom. Some groups saw this and copied the technique, moving their operation from the table to the floor.

One team was made up of five male students and one female student. Some male students were teasing others, playing with yardsticks, and not paying attention. The female student was reprimanding them to "pay attention, quit messing around, and to focus on the activity". It was interesting to see a student step up to take the role of team leader despite their teammates' behaviors.

None of the students finished constructing their payloads during the in-class workshop. They had the option of continuing operations before and after school on Wednesday, November 6 and Thursday, November 7. They had a hard deadline of

Thursday at 4:00 P.M. to finish their payload (*Table 3*). The payloads were returned to UND on Friday morning to undergo final inspection and assembly.

Table 3: October to November Schedule

October – November 2013 Schedule				
Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
28.	**29.**	**30.**	**31.** Presentation and student brainstorming day	**1.** In-Class Design
4. In-Class Design	**5.** Author led Construction Workshop in-class	**6.** Students continue with payload construction before and/or after school	**7.** Students continue payload construction before and/or after school. 4 P.M. deadline.	**8.** Dr. Fevig collects the completed payloads in the morning and brings them back to UND
11. No school; Veteran's Day	**12.** Payload train assembly at UND	**13.** Launch Day; 9:50 lift off 12:30 payload recovery	**14.** Data analysis at UND	**15.** Data analysis presentation to VMS students

= Days the author was with the students, instructing the activity
= Days Mr. Brent Newman led NSB instruction and activities
= Days Newman led a non-HAB instruction, finishing their Astronomy unit

Launch Day

In the early hours of Wednesday, November 13, preparations began for the dual-balloon launch. Winds aloft data was used in Balloon Track, which is a program that simulates the trajectory and landing site of the balloons due to jet stream conditions (Appendix E). Transferring this information into a GPS Visualizer, the estimated landing site was recorded and distributed to Newman and every chase vehicle. All battery packs were unplugged from their overnight charging stations, ready to perform at their full capacity.

Arriving at the football field of VMS, the graduate student launch team set each payload string on separate tarps. Each payload sensor had to be turned on and secured into the appropriate payload container. Then the payload containers were sealed using duct tape, which took much longer than anticipated. At 9:00 AM, the anticipated launch time, the team was still securing payloads and inflating the balloons. The students, teachers, and staff unfortunately had to stand around for an additional 50 minutes, waiting for the launch team to fix the technical issues. Students were preoccupied by an educational balloon physics lesson by Dr. Fevig and received NASA stickers from Ms. Nolby.

Some unanticipated delays arose from the payload chain. All of the students designed their payloads well, but the space that they allocated for the camera had to be used instead for the balloon string. The PowerShot digital camera was transported into another team's payload, which would permit images to be taken without any obstructions. Second, two student sensors had to be placed together into another container, due to a malfunctioning battery pack. The students were informed of this switch after the launch was complete, experiencing the unpreventable challenges that occur in real scientific missions. The empty containers were still utilized by housing the SPOT trackers.

Mr. Josh Borchardt took the lead with the helium tanks and filling equipment. One filling hose developed a leak, which left the team with one filling system. Even with this delay, filling was not suspended, just decelerated.

The SPOT trackers and HAM radios were all turned on and their transmissions were confirmed. Another impediment occurred while the team installed the primary tracking computer into the chase school bus. They realized the AC to DC cigarette-lighter adapter was missing, and the launch team attempted to establish an alternate charging method. Ultimately, there was no solution, leaving the school bus without an operational tracking platform.

At 9:15 AM, the first balloon was completely filled and ready to launch. Team members secured it for fifteen minutes, until the second balloon was filled. With everything tied off, taped up, and ready to fly, twelve eighth-grade volunteers were allowed to hold the payloads, six per payload train (Appendix F; Images 14 and 15). When all spectators had backed up from the launch site, the balloons were launched, one after the other. Ms. Courtney released the first balloon at 9:50 AM and Mr. Borchardt released the second balloon seconds after (Appendix F; Images 13 and 16).

Joyous applause, celebrations, and running ensued: the 12 eighth-graders participating on the chase ran to the school bus and the tracking team members left in three vehicles. The school bus was able to monitor Balloon 2 by following Mr. Badders chase vehicle and monitoring the online SPOT website. On the bus, Mr. Ben March shouted out altitudes to the students after receiving phone calls from Badders. Continuously switching sides of the bus while looking out the window, the students thoroughly enjoyed the balloon chase.

The middle school students were able to locate the payload chain right away. It was found near a dirt road, easily accessible to the large school bus. The bright orange payloads were seen in the distance, luckily avoiding a dense patch of trees, a few yards away. After Borchardt's chase vehicle obtained permission to go on the land and approach the payloads, the students were able to examine their structures.

Figure 2: Balloon Trajectories

Each balloon followed a similar trajectory, floating due east and surpassing 102,000 feet (Figure 2). Balloon 1 was filled with a little less helium than Balloon 2, causing it to ascend slower, travel farther to the east, and reach the peak altitude of 102,500 feet. Balloon 2, the balloon that the middle school students recovered, reached an altitude of 102,050 feet. It was fortunate that the students chased the balloon with the shorter float time.

While eating lunch and heading back to the middle school, the students were able to examine the shredded latex balloon and their payloads. The SPOT tracker unintentionally stayed on, transmitting the bus' progress back to Newman at Grand Forks. The students primarily discussed the smell of the latex, their desire for lunch, and most importantly, a restroom break. When traveling with so many young students, it is recommended to search out available restroom stops along the chase route.

Data Analysis Workshop

On Friday, November 15, 2013, the videos, images, and NeuLog sensor data were brought into the classroom, presented to all six classes. The students were astonished with the footage and data that *they* obtained. Many were standing up out of their seats, audibly admiring the views of 102,000 feet above them (Appendix F; Images 21 and 22).

After observing the level of audible amazement during balloon burst, which was shown frame by frame, it can be said that this was their favorite video. It was fun to watch the students silently await the "pop" of the balloon. At this point, the 30-foot-diameter balloon spun silently against the dark backdrop of space while every pair of eyes – students, teachers, and staff visitors – avidly stared at the screen, awaiting the burst. When the latex loudly burst into many "fingers" (Appendix F; Image 20), most students jumped and then laughed from being startled.

Some class periods received the unfortunate news that their experiment had malfunctioned. They understood this is an unavoidable obstacle while working on a science mission. The students realized that even though their inquiry-based project failed, they still received valuable information. If launched again, they would consider the errors in their design and ultimately perfect their payload.

CHAPTER V

RESULTS

Pre- and Post- Survey Results

The second group of questions on the surveys, following the gender and demographic questions, targeted the students' opinions on their future in high school. As seen in Table 4, a list of available high school classes was offered to the students, who could circle up to two of their most anticipated and least anticipated subjects. Accurate data could be extrapolated from the surveys when the students provided their top two answers.

Two of the most valuable questions in the pre- and post-survey are the *Most Anticipated Classes* and *Least Anticipated Classes for High School*. These survey questions are vital to the thesis question that will prove or disprove if the students' outlook on STEM education was impacted positively or negatively.

The students (n = 124) were asked to select up to two subjects that they were most looking forward to take and least looking forward to take in high school. The actual survey questions were phrased in a way that the students would completely understand: "In high school, I am *most* looking forward to study" and "In high school, I am *least* looking forward to study". The differentiating words, most and least, were italicized to emphasize the questions' tone. This way, there would be no accidental misconstruing of the research data.

Table 4: Class Options for High School

High School Classes	
Fine Arts	Music (Choir, Band, Jazz Band, Orchestra), Art, Theater Art, and Military Science
Math	Algebra, Geometry, Mathematical Modeling, Applied Math, Pre-Calculus, Discrete Math, Probability & Statistics, and Advanced Placement (AP) Calculus
Science	Physical Science, Biology, Chemistry, Geology, Physiology/Anatomy, Physics, and AP Biology
Social Studies	Global Education, United States History, AP U.S. History, American Government, AP Government, Economics, AP Economics, North Dakota Studies, The Great Wars, Psychology, Sociology, and Japanese Studies
Health/PE	Foundation of Fitness, Health, Personal Wellness, Strength and Conditioning, Team Sports, Advanced Aquatics, Aerobics/Group Exercise, Sports and Games, Dance, Breathe & Stretch and Cardio Training, and General Physical Education
Business/Marketing	Keyboarding, Computer Applications, Personal Finance, Accounting, Personal & Business Law, Video Productions, Microsoft Word, Web Pages, Microsoft Excel, Microsoft PowerPoint & Publisher, Multimedia & Image Management, and Marketing
Foreign Language	French, Spanish, German, and Latin
English	English, English Composition, English Literature, Film Study, Reading, Creative Writing, Journalism, AP Language & Comp. and AP Literature & Comp.

(Grand Forks Public Schools, 2014)

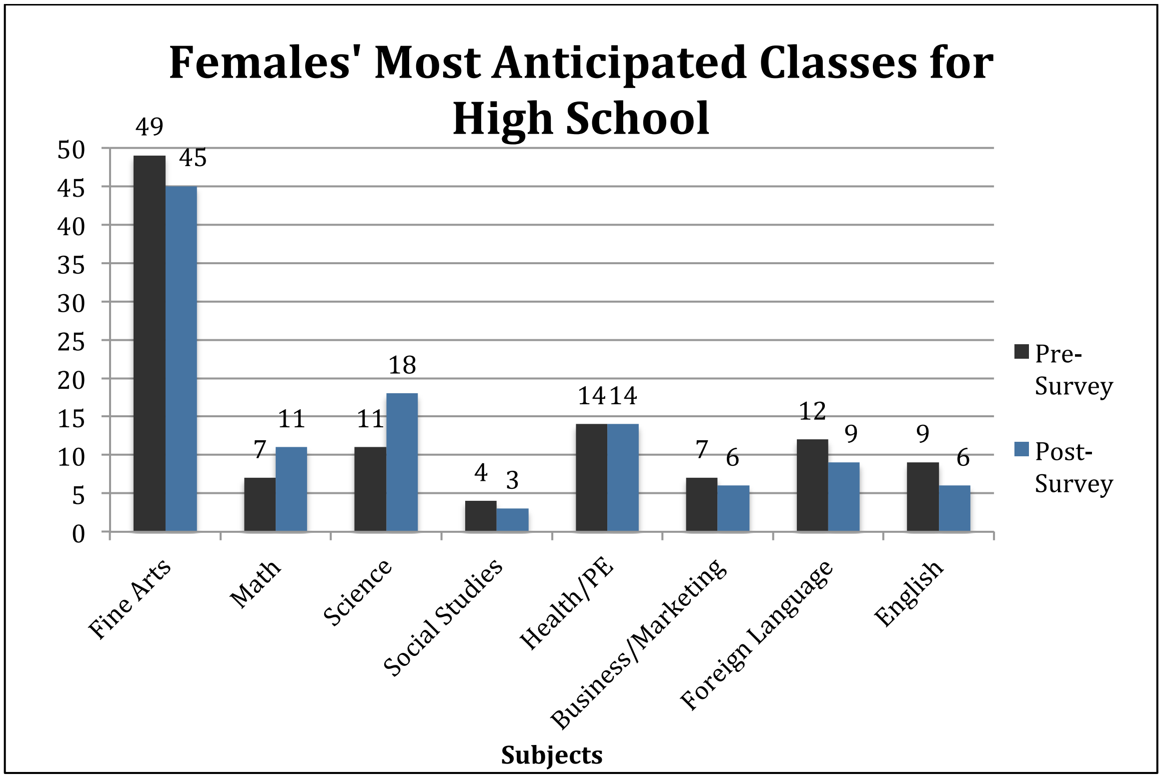


Figure 3: Females' Most Anticipated Classes for High School

The female responses for *the Most Anticipated Classes for High School* (Figure 3) displayed a sharp spike in Fine Arts. The female students wanted to take Fine Arts – consisting of Music (Choir, Band, Jazz Band, Orchestra), Art, Theater Art, and Military Science – before and after the ballooning experience. Fine Arts surpassed all the other subject areas with 49 pre-survey counts and 45 post-survey counts.

Table 5: Females' Most Anticipated Classes - Percent Change

Subject	**% Change**
Fine Arts	-8.2
Math	57.1
Science	63.6
Social Studies	-25
Health/PE	0
Business/Marketing	-14.3
Foreign Language	-25
English	-33.3

The target subjects, math and science, both increased from the pre-survey to the post- survey, supporting the hypothesis. Seven and eleven female students defined math and science, respectively, to be their most anticipated class in high school. After the ballooning experience, 11 and 18 female students defined math and science, respectively, as their most anticipated high school class. Overall, math increased by 57.1 percent and science increased by 63.6 percent. Table 5 displays the percent changes for all eight classes.

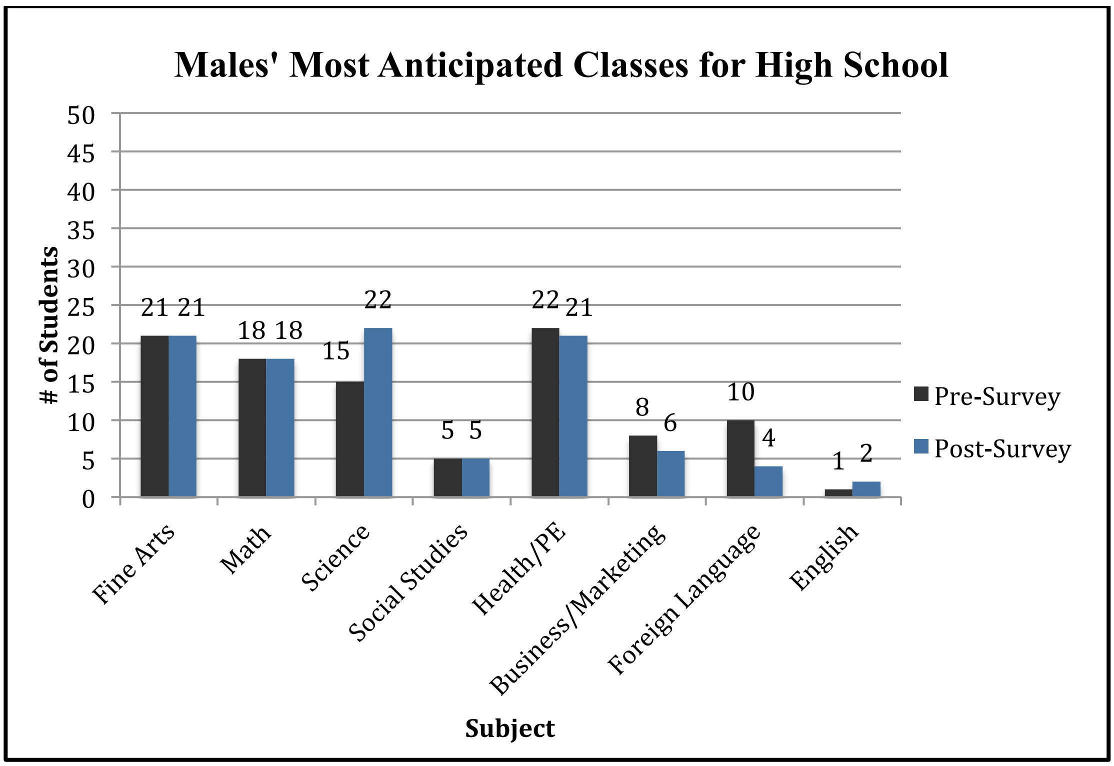


Figure 4: Males' Most Anticipated Classes for High School

The survey question polling the males' preference to high school classes (Figure 4) yielded quite different results than the females; there is no prominent spike in data. Social Studies, Business/Marketing, Foreign Language, and English were favored considerably less than the Fine Arts, Math, Science, and Health/PE.

Table 6: Males' Most Anticipated Classes - Percent Change

Subject	% Change
Fine Arts	0
Math	0
Science	46.6
Social Studies	0
Health/PE	-4.5
Business/Marketing	-25
Foreign Language	-60
English	100

The targeted survey topics, math and science, displayed quite distinctive results. Math remained constant from before and after the ballooning activity. Fifteen male students confirmed that they were eager to study science in high school in the pre-survey. After the ballooning experience, 22 male students had a strong interest in science, producing a 46.6 percent increase. Table 6 displays all of the percent changes for the males' most anticipated classes.

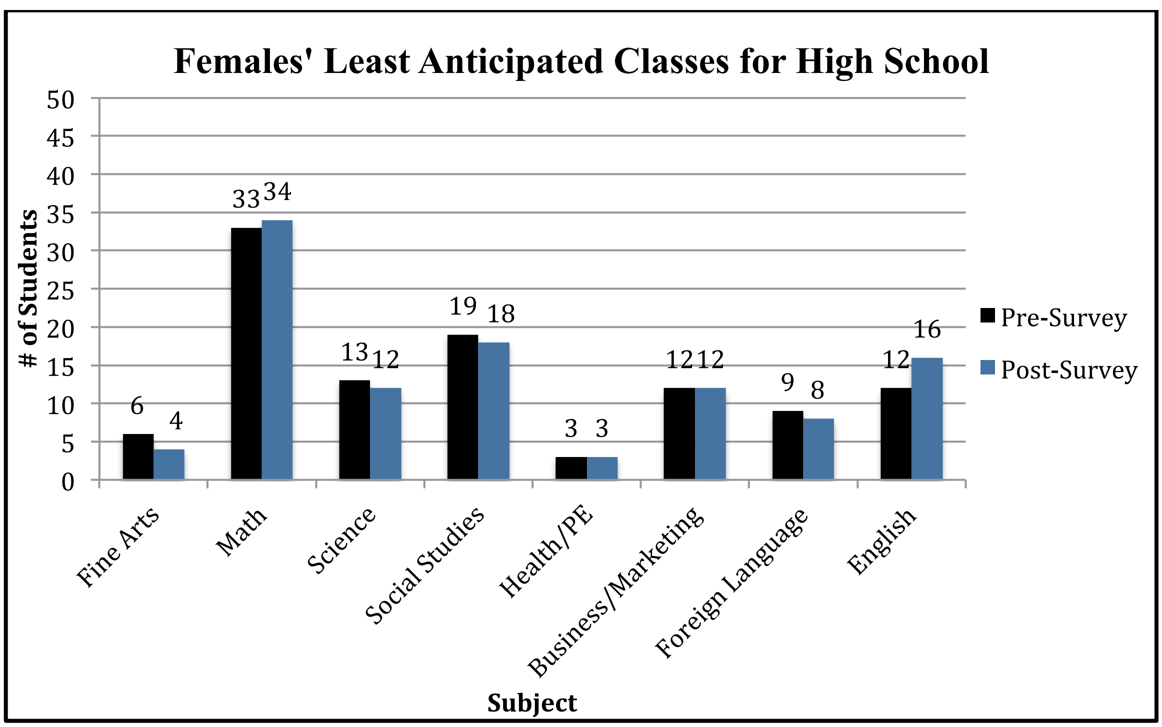


Figure 5: Females' Least Anticipated Classes for High School

The total number of female students (n = 107) who answered the survey question, "*the Least Anticipated Classes in High School"* was identical for the pre-and post-survey. The female students displayed a clear dissatisfaction when they thought of learning high school math, as seen in Figure 5. There is a prevalent spike in math compared to the other subject choices. After comparing the post-survey results to the pre-survey, math displayed a decrease by -2.9 percent (Table 7). The percent change of the other seven classes can be seen in Table 7.

Table 7: Females' Least Anticipated Classes - Percent Change

Subject	% Change
Fine Arts	50
Math	-2.9
Science	8.3
Social Studies	5.6
Health/PE	0
Business/Marketing	0
Foreign Language	12.5
English	-25

Focusing on high school science class data, female students displayed equal sentiments before and after the ballooning experience. With 107 participants, 13 showed discomfort with science on the pre-survey and 12 on the post-survey. The one-student difference is statistically insignificant and it can be deduced that the science category was not affected by the experiment. The post-survey results were intended to decline in the math and science regions, proving the students have a stronger apposition to the STEM subjects.

The least anticipated class that male students have for high school is English, which includes English, Speech Communications, Film Study, Creative Writing, and Journalism (Figure 6). One key result from the post-survey was the increase in both

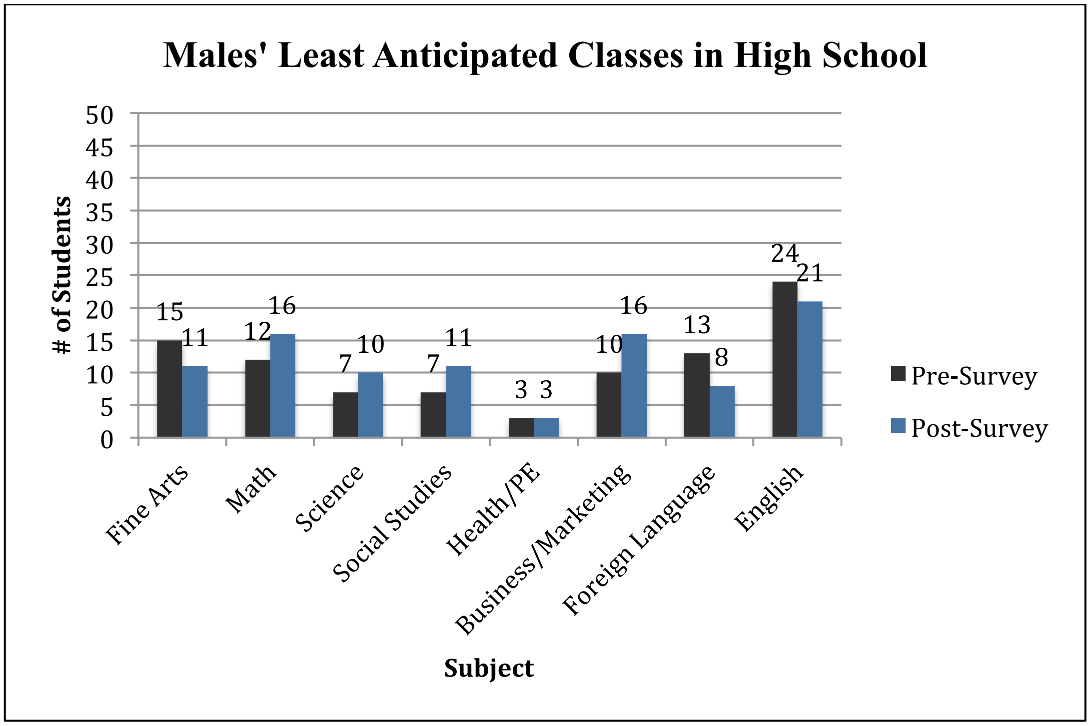


Figure 6: Males' Least Anticipated Classes for High School

Math and Science. The goal of the balloon experiment was to introduce the students to a non-intimidating, fun side of Math and Science. The consensus for Math increased from 12 to 16 males, a change of 25 percent, and Science increased from 7 to 10 males, a change of 30 percent (Table 8). The only other class that also increased was Business/Marketing, increasing by 37.5 percent.

Table 8: Males' Least Anticipated Classes in High School - Percent Change

Subject	% Change
Fine Arts	-36.6
Math	25
Science	30
Social Studies	36.6
Health/PE	0
Business/Marketing	37.5
Foreign Language	-62.5
English	-14.3

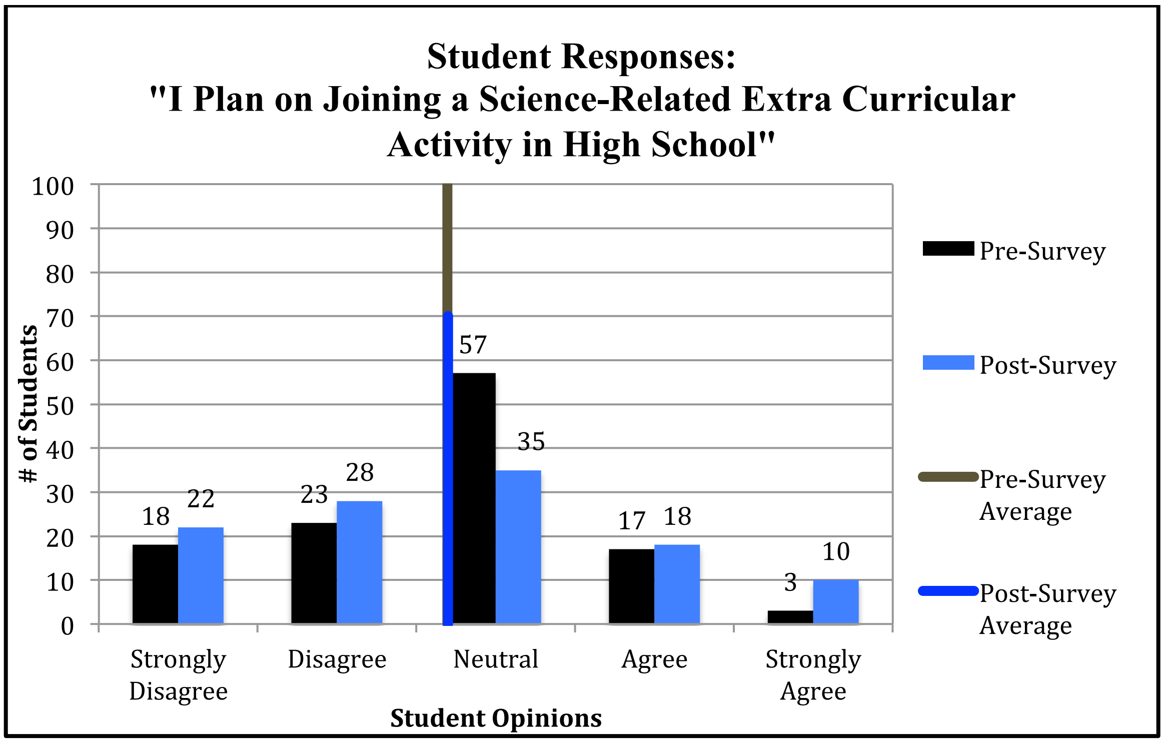


Figure 7: Student Responses - "I Plan on Joining a Science-Related Extra Curricular Activity in High School"

The first Likert-Scale question asked the students if they were interested to join a science-related extra-curricular activity in high school. This implies that they either already had a passion for an activity that expanded from one of the core classes or not. If the ballooning experience opened up more STEM interests, such as robotics, ballooning itself, or rocketry, the post-survey data would shift towards “strongly agree”.

The results in Figure 7 supported the null hypothesis stating the students' were not persuaded to join an extracurricular activity after participating in the NSB project, experiencing a 0.001 percent increase ($\bar{X}_1$= 2.69, n = 118; $\bar{X}_2$ = 2.69, n = 113; p = 0.42, α = 0.05).

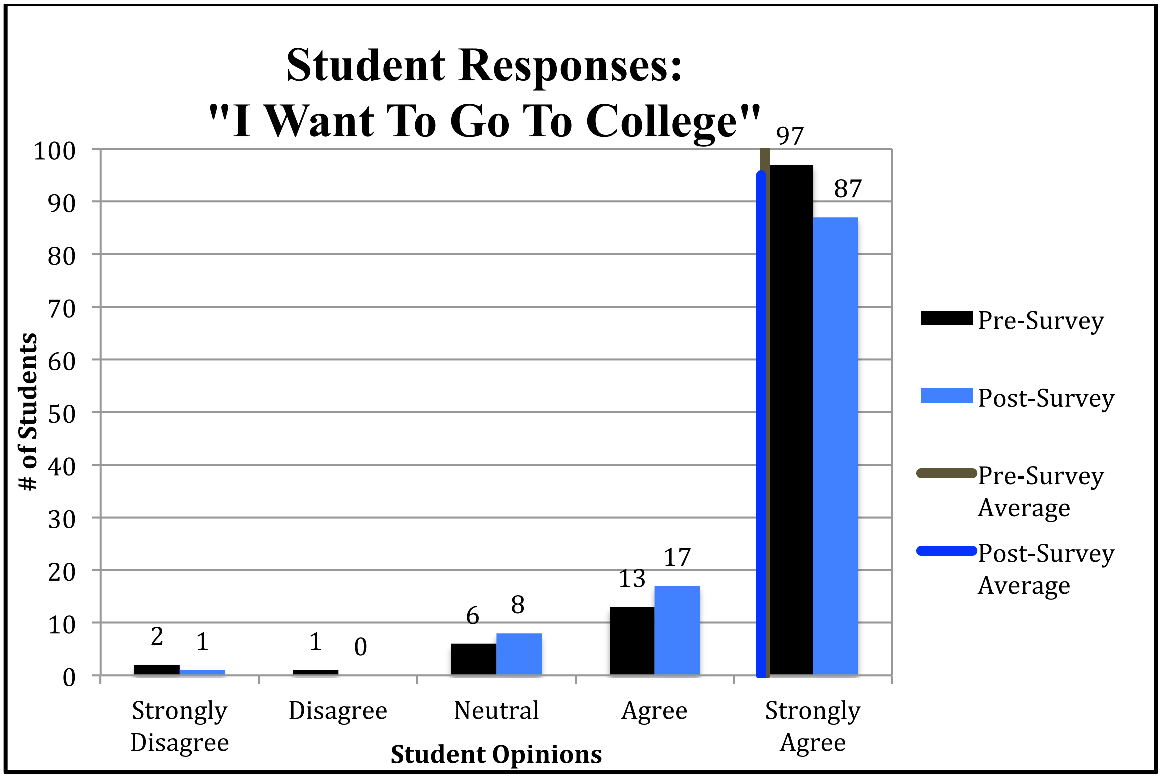


Figure 8: Student Responses - "I Want to go to College"

The students *strongly agreed* that they would pursue a college career after completing high school (Figure 8). The objective of this poll question was to see if the ballooning experience influenced the students' disposition of attending college. There was a 0.005 percent increase from the pre-survey to the post-survey, which supports the null hypothesis ($\bar{X}_1$ = 4.69, n = 119; $\bar{X}_2$= 4.67, n = 113; p = 0.40, α = 0.05).

Because nearly 82 percent of students *Strongly* want to attend college, the next step was to see if they were interested in the University of North Dakota (Figure 9).

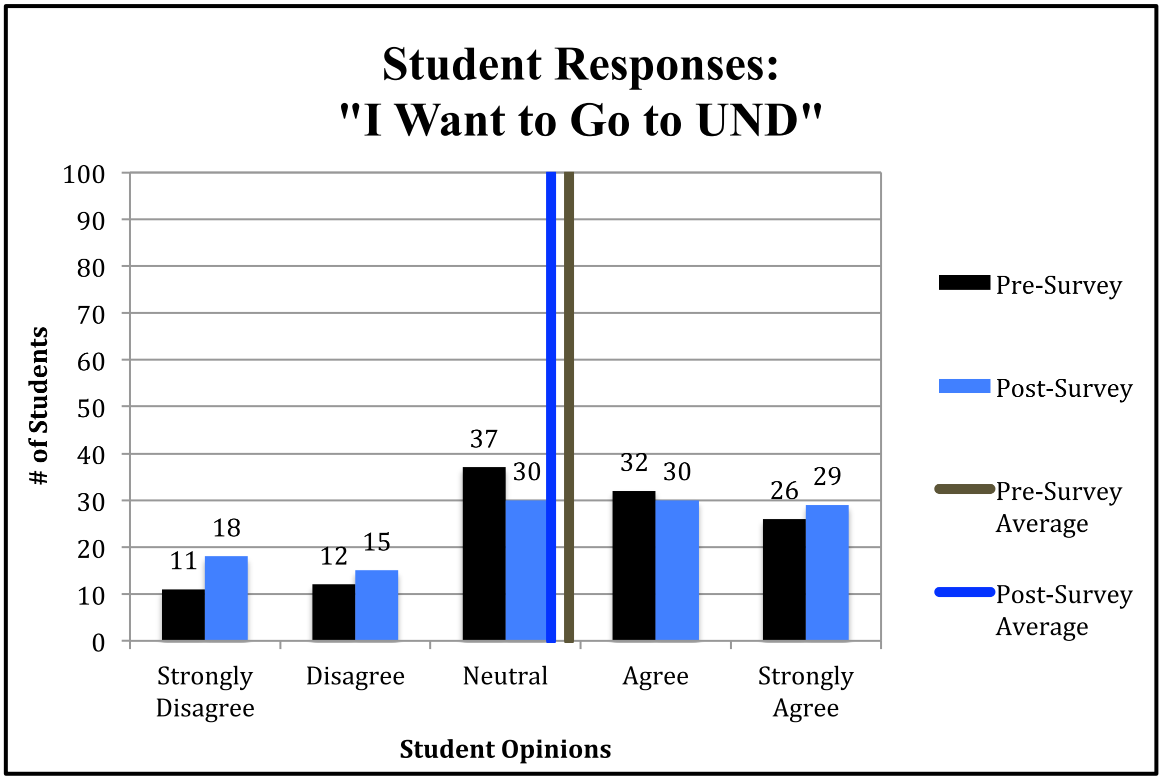


Figure 9: Student Responses - "I Want to Go to UND"

The students were surveyed to see if the ballooning experience, administered by UND, would influence their decision to apply to the school. The students reported a *neutral* bias towards attending UND and the $\Delta\bar{X}$ of 0.04 was insignificant ($\bar{X}_1 = 3.42$, $n = 118$; $\bar{X}_2 = 3.30$, $n = 122$; $p = 0.31$, $\alpha = 0.05$). This supported the null hypothesis that the NSB project did not influence their decision to attend UND. The probability that the results changed due to the ballooning experience due is not supported.

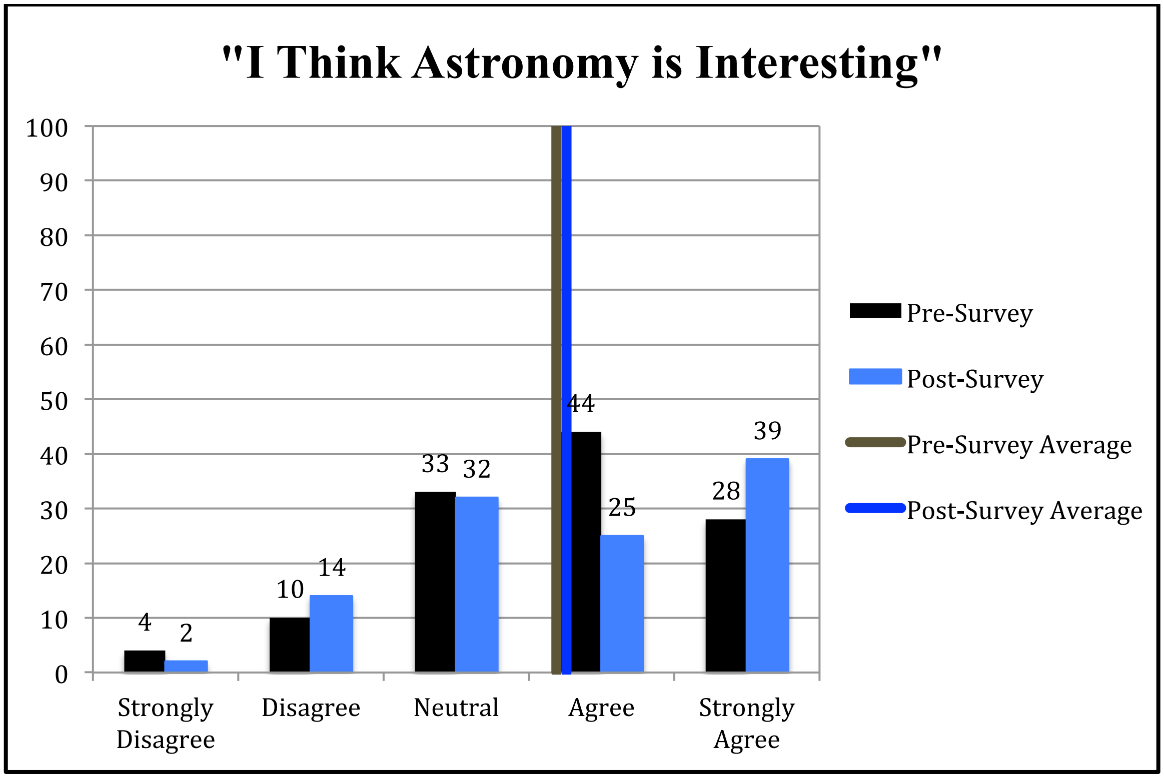


Figure 10: Student Responses - "I Think Astronomy is Interesting"

As mentioned above, this study coordinated the balloon launch at the same time as Mr. Newman completed his astronomy unit. The poll question, "*I Think Astronomy is Interesting*" was supplied to the students before and after the balloon launch. The students may have realized that science lessons learned learn didactically in the classroom could be applicable using real-life experimentation, enhancing their textbook-style lessons of astronomy. Ultimately, the null hypothesis was supported; the student interest level in astronomy did not improve ($\bar{X}_1$= 3.69, n = 119; $\bar{X}_2$= 3.76, n = 112; p = 0.40, α = 0.05). The probability that the $\Delta\bar{X}$ is due to random chance is high.

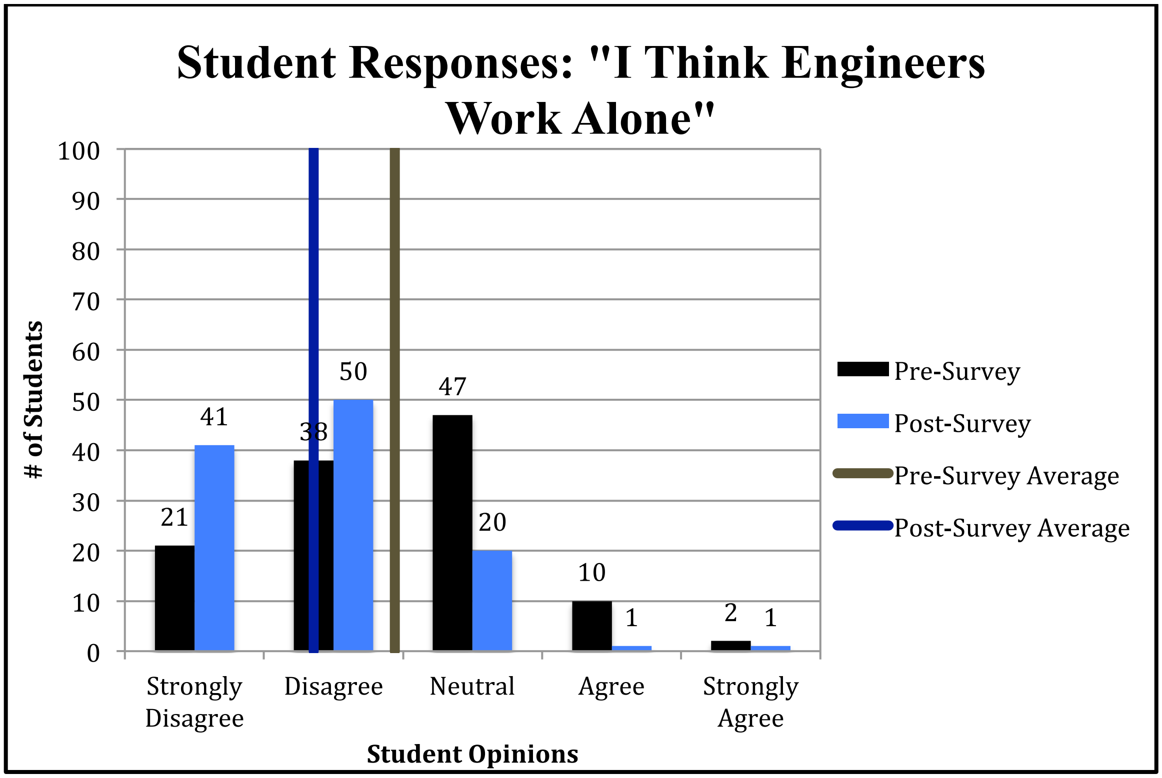


Figure 11: Student Responses - "I Think Engineers Work Alone"

Before the students collaborated together on their NSB project, they were uncertain if engineers worked alone on projects (Figure 11), producing a census closer to *Neutral*. After the NSB project, the students understood that as space scientists and aerospace engineers, they had to collaborate with their peers, similar to professional engineers ($\bar{X}_1$= 2.44, n = 118; $\bar{X}_2$= 1.86, n = 113; p = $1.16\ x\ 10^{-6}$, α = 0.05). Figure 10 was the only student poll that resulted in a significant change, supporting the hypothesis.

At first, the students answered the poll with uncertainty, with a median value around the *Disagree* to *Neutral* areas of the spectrum. After the in-class work and the launch of the balloons, the average experienced a 0.24 percent decrease (supporting the VMS study), positioning the census closer to the *Disagree* category. The t-Test analysis confirms the shift was significant and caused by the thesis study.

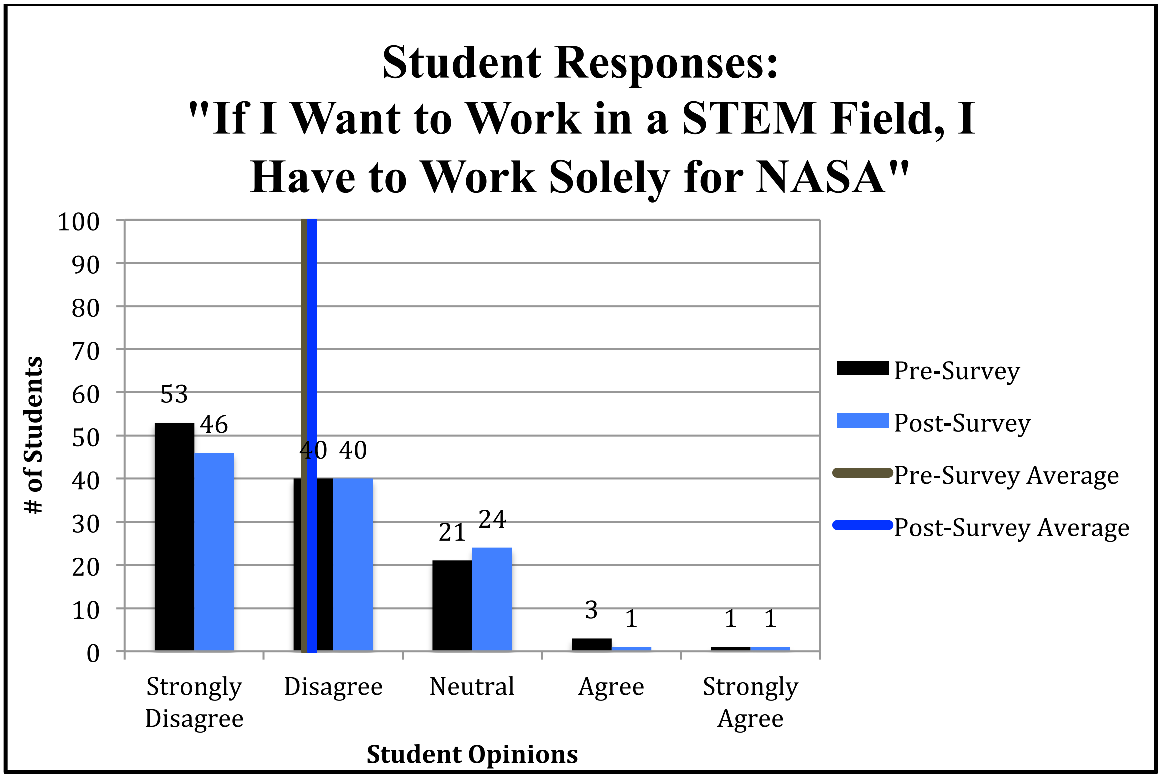


Figure 12: Student Responses - "If I Want to Work in a STEM Field, I Have to Work Solely for NASA"

Figure 12 displays the students' opinions on employment in a science field. The expected outcome was positioned to the left side of the x-axis. Even before watching introductory presentation during the first workshop, the students were aware that you do not need to work at NASA to participate in a science field. The outcome produced a null hypothesis, stating the students did not learn that you do not need to work for NASA to work in a STEM field ($\bar{X}_1$ = 1.81, n = 118; $\bar{X}_2$= 1.85, n = 112; p = 0.41, α = 0.05). The pre to post averages experienced a 0.02 percent change. Overall, the survey distribution appeared as expected: most of the participants responded with a value in the negative region of the spectrum, *Strongly Disagree* and *Disagree.*

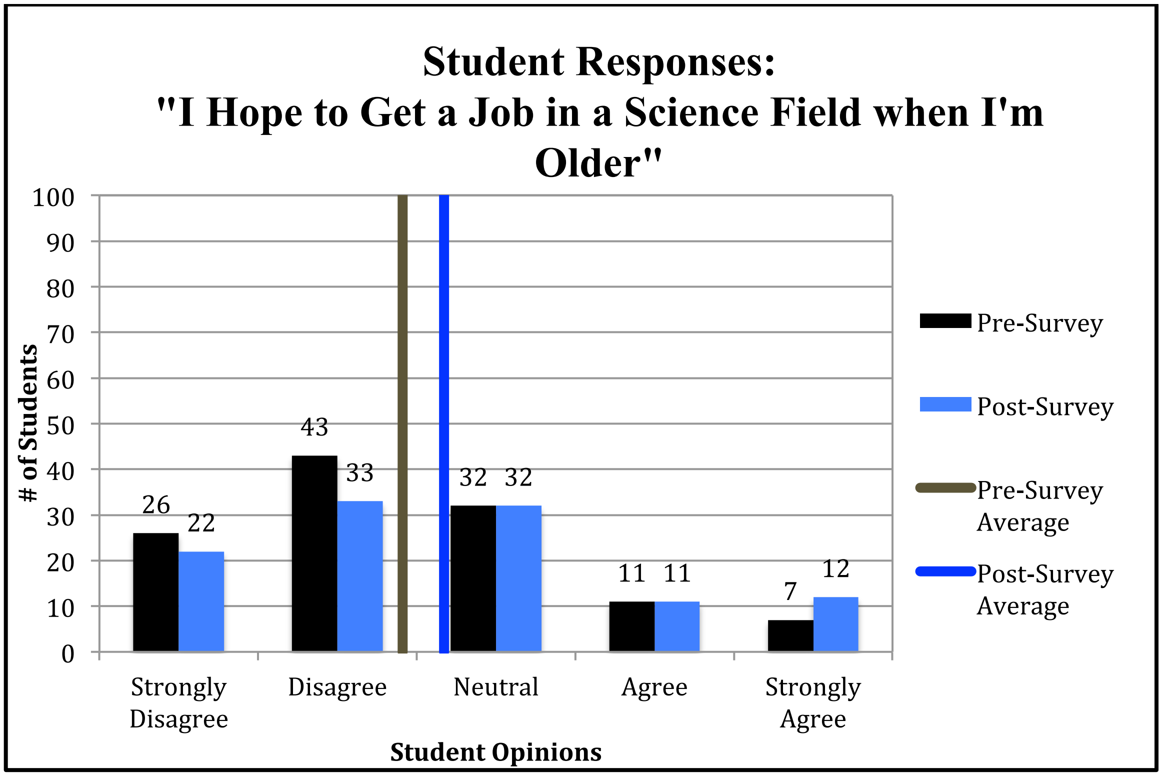


Figure 13: Student Responses - "I Hope to Get a Job in a Science Field When I'm Older"

The students felt uncertain or conflicted while considering a science-related job for their future (Figure 13). After the post-survey, their disposition towards the subject changed by 0.09 percent ($\bar{X}_1$ = 2.41, n = 119; $\bar{X}_2$= 2.62, n = 110; p = 0.09, α = 0.05). Without a p value greater than five percent, the hypothesis was determined null because the thesis project did not change the students' opinions on obtaining a job in a science field.

The last Likert-Scale survey question tested to see if the ballooning experience changed the students' career plans, supplying ideas with the STEM activity. Figure 14 displays that the students possessed predispositions, *Strongly Agreeing* that they already had career plans, unchanged by the balloon project. This supports a null hypothesis

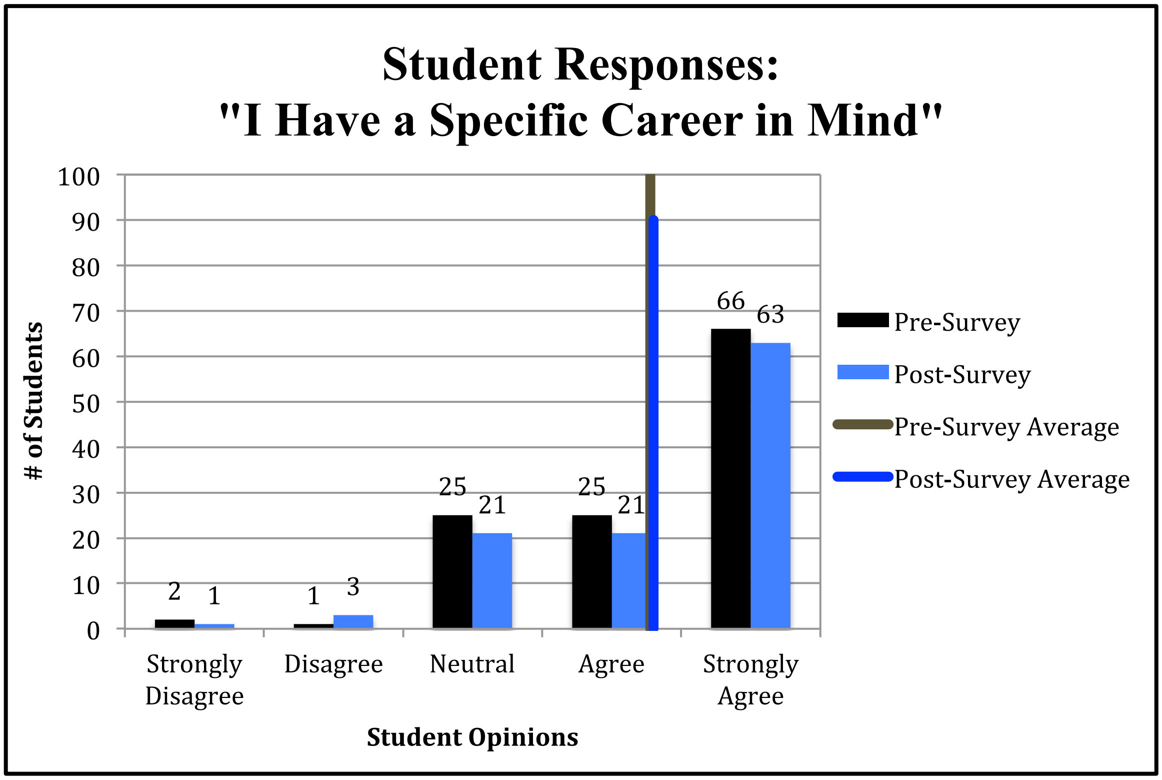


Figure 14: Student Responses: "I Have a Specific Career in Mind"

and a 0.006 percent change; the NSB project did not influence the students ($\bar{X}_1$= 4.28, n = 119; $\bar{X}_2$= 4.3, n = 109; p = 0.19, α = 0.05).

The subsequent section following the demographic questions is the generalized retrospect questions. These target both male and female genders, examining the students' post-balloon likes and dislikes. Each student could select up to two possible answers in this category. Figure 15 displays the students' most favorite part of the ballooning experience. The male students ($n = 49$) greatly enjoyed the payload construction process and the filling and launching of the balloon, with very comparable numbers (19 and 17, respectably). The female students ($n = 54$) had a more prominent spike in their results compared to the males. The females clearly enjoyed the launch process, surveying at 57 percent.

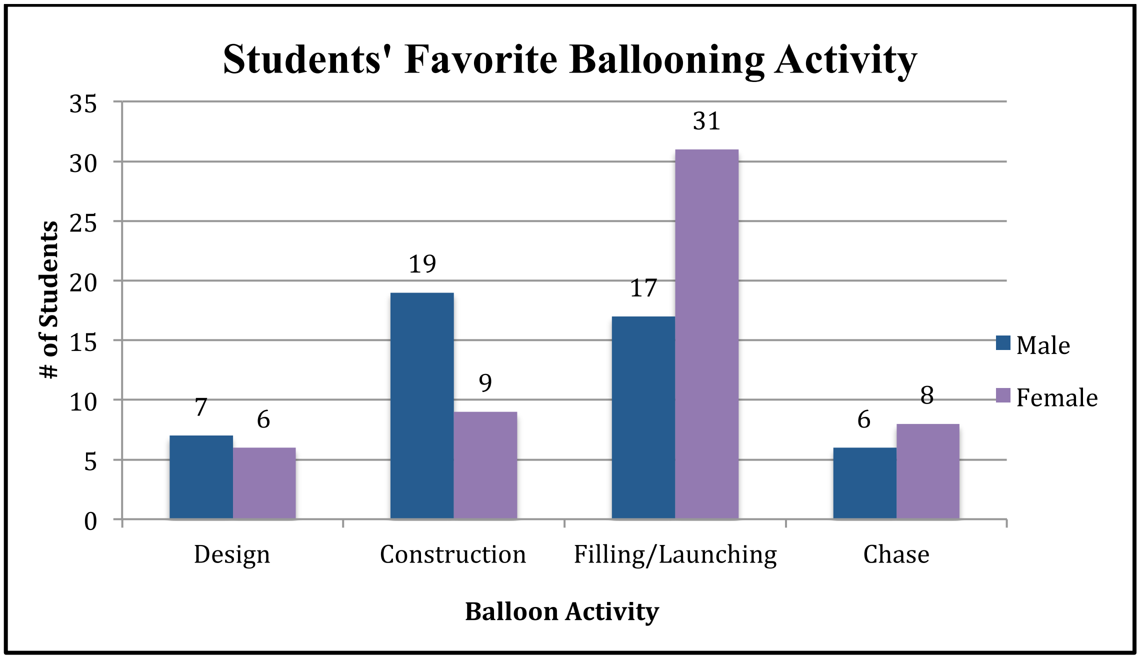


Figure 15: Students' Favorite Ballooning Activity

There were multiple Likert style questions in the post-survey that focused on the overall attitude towards the overall experiment, determining if the endeavor is rewarding enough be repeated with another school. These questions did not have a before and after analysis, as did Figures 6-12.

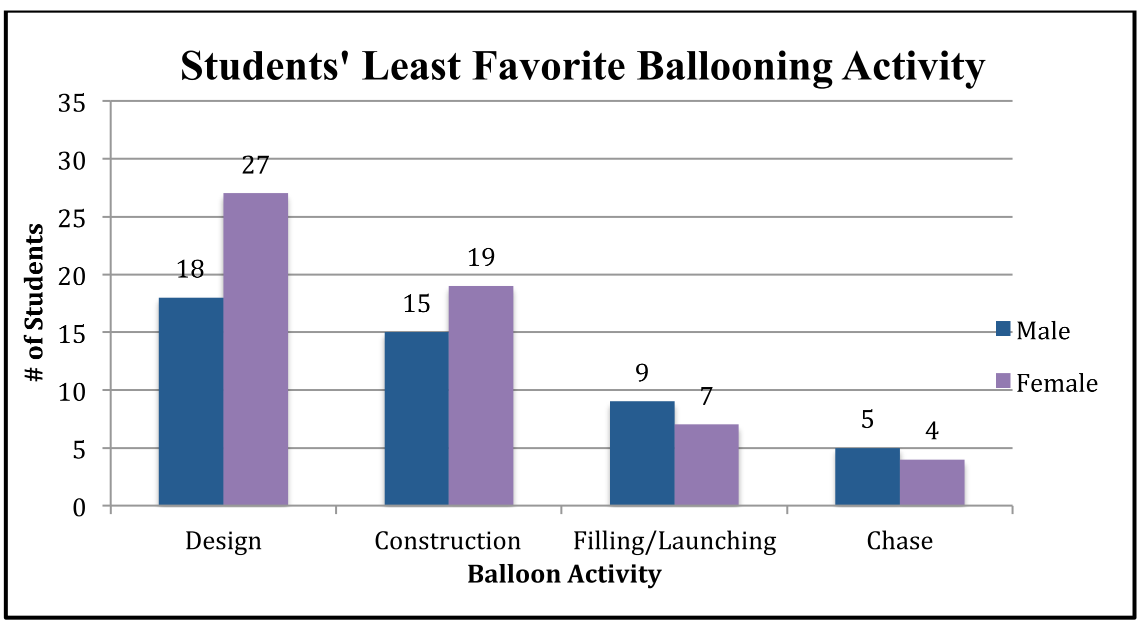


Figure 16: Students' Least Favorite Ballooning Activity

The male and female students also shared their least favorite aspect of the ballooning experience (Figure 16). Both male and female results displayed similar values and their proportions. The least enjoyed balloon activity for both the female ($n = 57$) and male students ($n = 47$) was the design process.

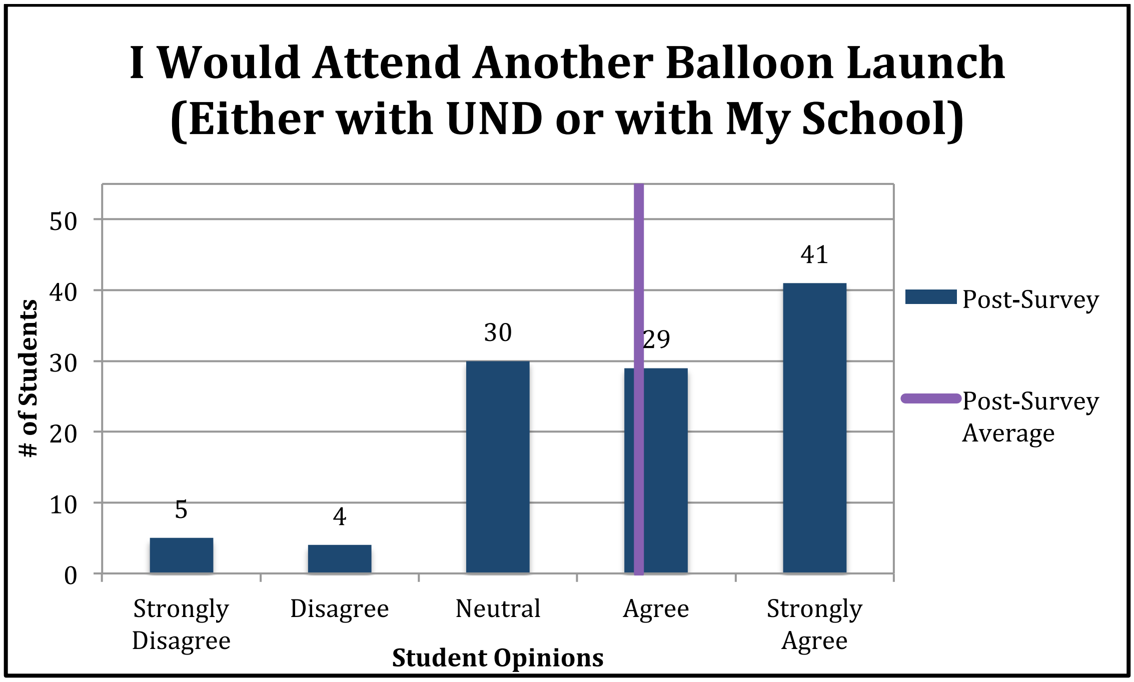


Figure 17: "I Would Attend Another Balloon Launch (Either with UND or with My School)"

The students *agreed* that they would attend another NSB launch ($\bar{X} = 3.9$, $n = 109$, Figure 16). The survey specified a NSB launch either hosted by UND or a similar experiment with their school. There were nine students who either *strongly disagreed* or *disagreed* that they would voluntarily participate in a similar experience.

As seen in Figure 18, the students also would *agree* to recommend their ballooning experience to family and friends ($\bar{X} = 4.08, n = 109$).

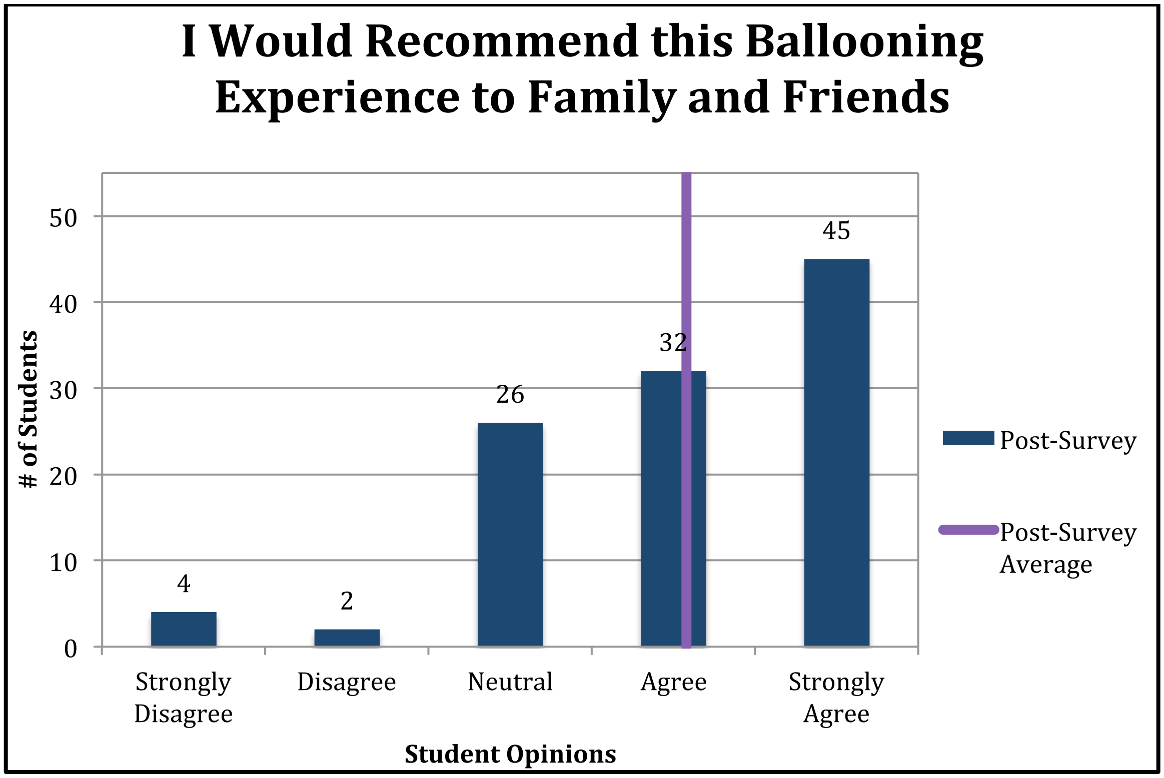


Figure 18: "I Would Recommend UND's Balloon Launches to Family and Friends"

The students also *agree* that they would recommend this NSB experience to their peers ($\bar{X} = 4.27, n = 109$, Figure 18). The pattern of *strongly disagree* and *disagree* data has continued to decrease, with one and two students, respectively.

Overall, the ballooning experience was quantitatively expressed as a success, as seen in Figure 20. Both male and female students produced positive results on the post-survey.

The students were asked to express their opinion on the experiment being educational, fun, and inspiring. The educational and fun median fell between *Agree* and *Strongly Agree*, in a location closer to *Agree*. The students felt less inspiration during the experiment, forming a median opinion slightly above the neutral bar. Looking at the modes for these data points place "fun" as the most selected category, located in *Strongly Agree*.

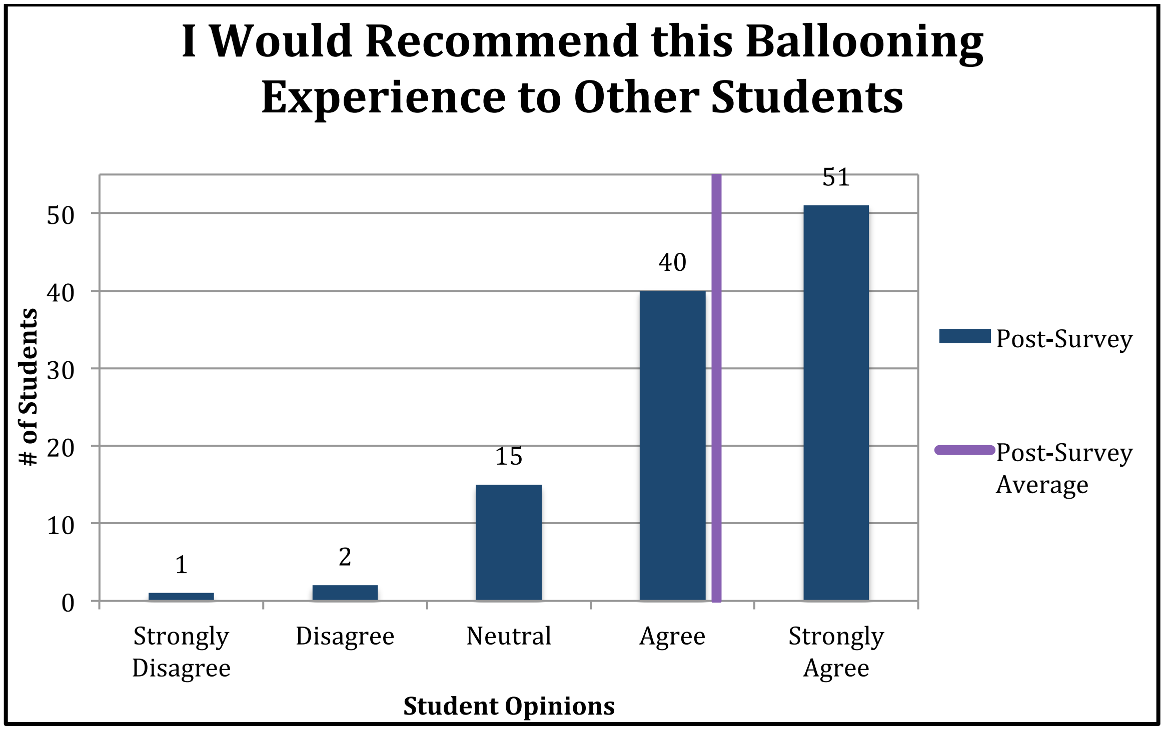


Figure 19: "I Would Recommend this Ballooning Experience to Other Students"

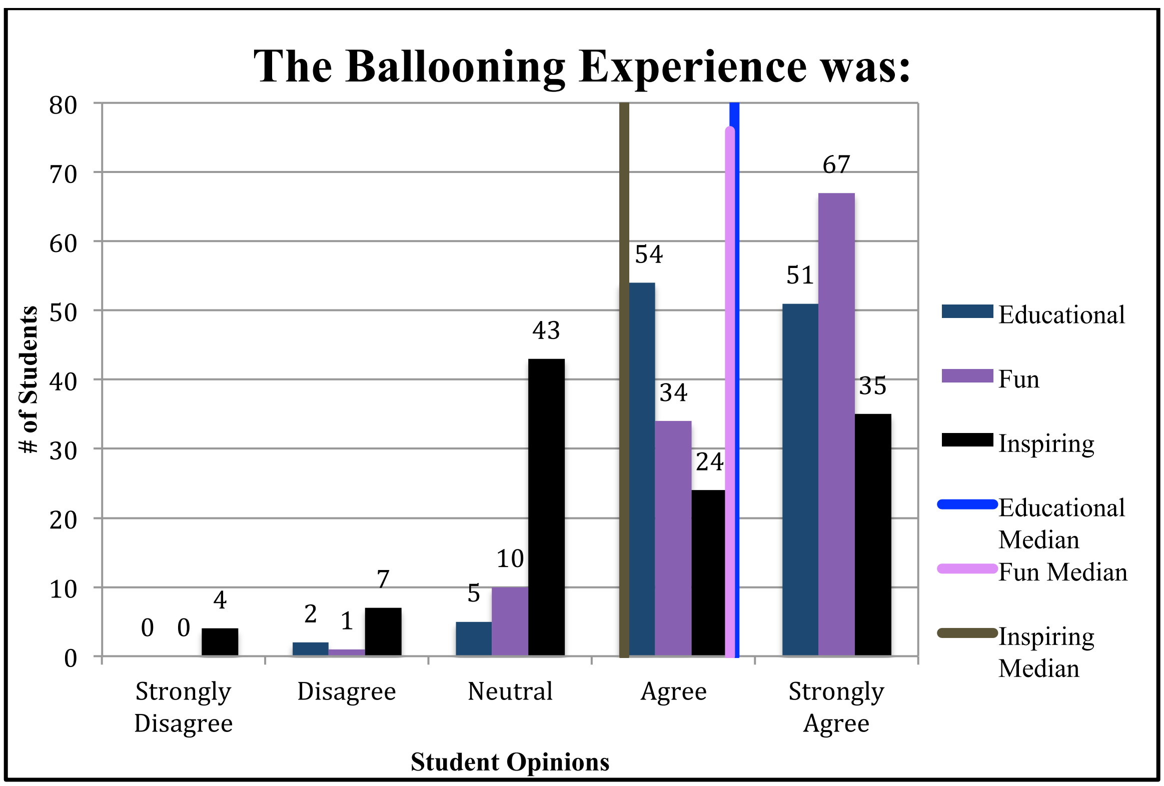


Figure 20: "The Ballooning Experience Was..."

The last section of the post-survey had open-response questions. The first question was, “*Please describe how you felt about the entire ballooning experience”* (Figure 21). The students formulated their own vocabulary, phrases, and opinions without the accidental bias from a survey. This section gave the students complete freedom to illustrate their true disposition towards the NSB project. There were many positive phrases, including: *I enjoyed coming to science class, I felt honored, and this was a one-time experience*. Contrary, there were negative phrases that will be considered for future in-class balloon workshops. These included: “*waste of time, rushed, hectic, and boring*”.

The second open responses question asked the students to mention one thing they would change for future students. The eighth-graders provided beneficial and useful information that can be used for future launches. There were patterns in their responses that were categorized into five major sections.

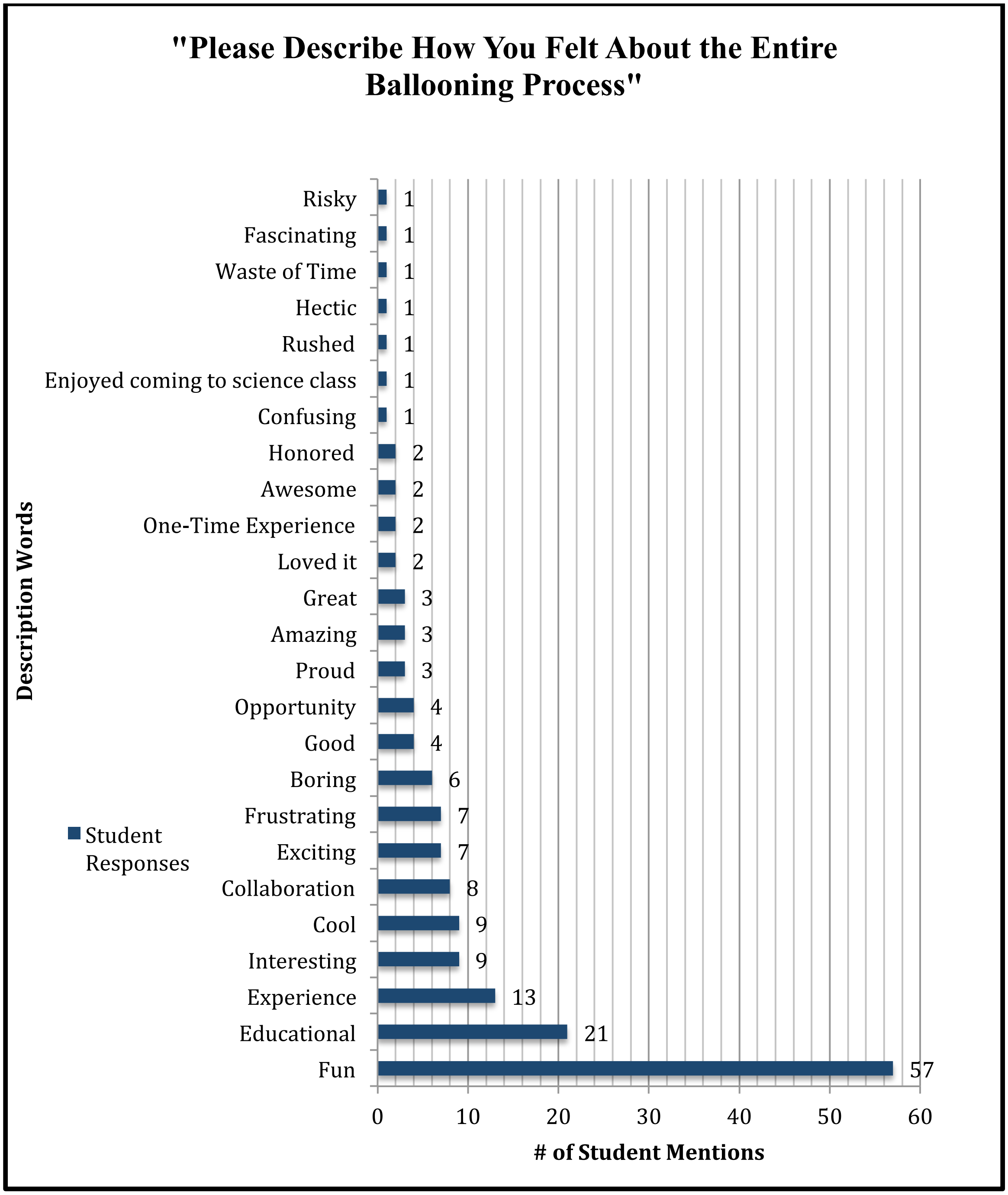


Figure 21: "Please Describe How You Felt About the Entire Ballooning Experience"

Table 9: Future Considerations for Instructors, by the Students
Smaller groups (2)
Teachers should assign roles
Who holds the payloads when they're launched
Talk more about **what we were suppose to learn**
End of school so it would be **warm (2)**
Have a little more **interaction with balloon** while its in the air
Make deadlines more clear

First, the students brought up ideas that should be considered by the instructor (Table 5). Some students were concerned with the way they were assigned groups, roles in the groups, and project deadlines. Standing outside in the North Dakotan November climate was also mentioned twice, suggesting a launch at the end of the school year, when its warmer. One student wanted a more in depth presentation covering what they should have learned, since their sensor malfunctioned.

Table 10: Payload Concerns, by Students
More cameras and pictures
Double check your payload before launch (infrared camera did not work) (4)
More than one thing in the box (2)
Different devices to launch (2)
Everyone should take part in designing and making the payloads (3)

The second topic the students mentioned was payload concerns (Figure 6). They wanted to add to the containers in case one experiment failed, as many did. Three students wanted to take part in all design and construction aspects. This emphasizes how eager the students were and how motivated they were to learn new material.

The students were concerned with the number of students who were chosen to join the balloon chase (Table 7). Their suggestions included two people per team (instead of the one) attend the chase. There were only two binoculars on the bus

Table 11: Bus Chase Considerations, by the Students
More people go on the bus (7)
Two people per team
Everyone (6)
More binoculars
People voted for someone else (for bus chase) (2)

during the chase, which caused the students to request additional pairs for the future. Also mentioned was the process of how students were chosen to attend the chase. For this launch, Newman selected the twelve students himself. Some expressed that they should have been able to vote or prove why they should have gone on the chase.

Table 12: Time Concerns, by the Students
Longer time in class to design/build payloads (16)
Use your time wisely with construction (6)
Deadlines further away (3)

The students also requested additional time for the design and construction workshop (Table 8). Their main concern was that they had to finish their project before and after school for the next two days. Over 16 students dedicated their replies towards this problem.

Table 13: Future Advice for Student Involvement/Cooperation, by Students
Students should be graded on **communication**
Putting some kids in same group where **they all get along** (2)
We would work harder and better together if we got to **pick our own groups (2)**
A lot of people **weren't getting their work done** (2)
Do your job because some people had to do other peoples' jobs (4)
Nothing (28)

Lastly, many students were frustrated with their team relationships (Table 9). To imitate a real life science mission, the students were assigned team members by Newman.

Students commented about how they had uncooperative teammates, communication problems, and had to finish others' jobs.

Lastly, the most frequent description that the students used was *nothing*, meaning they enjoyed the balloon activity just the way it was (Table 9). Twenty-eight students were pleased with the methodology and performance of the NSB project. This could boost the performance of the project, or signify that they could not think of something to write while brainstorming in class.

CHAPTER VI

DISCUSSION AND FUTURE WORK

Validity of Student Responses

Analyzing the socioeconomic status of the school district was pertinent for the validity of the surveys. With assistance from Dr. Ingwalson, it was discovered that many students at VMS qualify for reduced or free lunches every year. A free or reduced lunch is provided to students who are eligible for the government's program that subsidizes meals for children from low-income households (ProPublica, 2010). In 2010, the USDE reported 51 percent of VMS students were eligible for reduced or free lunches, compared to the 27 percent state average. At the district level, 35 percent of students were eligible, placing VMS above both averages (ProPublica, 2010). With an estimated population of 67,472 citizens, 16.5 percent of the individuals are under the poverty line (United States Census, 2010).

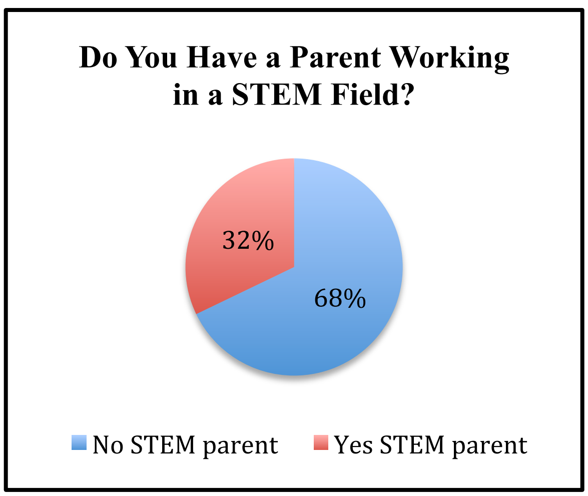


Figure 22: Parents Working in a STEM Field

As seen in Figure 22, 68 percent of students reported that their parents do not work in a STEM field. There are so few occupations heavily involved in a STEM field because Grand Forks has primarily business and service-related occupations.

The United States Census Bureau has characterized the following socioeconomic demographics for Grand Forks (2010):

Table 14: Grand Forks Socioeconomic Demographics

	Percentage
Ethnicities in Grand Forks, ND	
White	90.3
American Indian	2.5
Two or More Races	2.4
Black or African American	2.0
Asian	1.9
Native Hawaiian and Pacific Islanders	0.1
Other	0.8
Top Five Occupations in Grand Forks, ND	
Management	34.4
Sales and Office Occupations	24.9
Service Occupations	20.3
Production, Transportation, and Material Moving Occupations	10.5
Natural Resources and Construction	9.9
Top Five Main Industries of Grand Forks, ND	
Educational Services and Health Care	32.4
Retail Trade	15.2
Arts, Entertainment, Recreation, and Food Services	10.3
Manufacturing	6.0
Construction	5.9

(United States Census Bureau, 2010)

In 2010, the median household income for Grand Forks was $46,392 (United States Census Bureau, 2010). Almost 75 percent of all of Grand Forks employees were salary workers (United States Census Bureau, 2010). Grand Forks' demographic information would not have fulfilled the thesis objective of calculating how influential the parents' roles in STEM were to the students. It was decided that this comparison would not have produced exploitable results.

Using data from the USDE, ProPublica discovered that states and schools provide poor students fewer educational programs, including AP classes, gifted programs, and advanced science and math classes (2010). The VMS enrollment rate for gifted and talented students is five percent, which could potentially hind the students' future academics. The students may have fewer chances to push themselves to learn challenging and competitive material. The ND state average for gifted and talented students is 13 percent, notably beyond VMS levels (ProPublica, 2010).

Discussion of Pre- and Post Surveys

The most critical aspect in the students' learning experience was having them master the engineering process. The eighth graders were introduced to the scientific method earlier in the school year and the NSB project was the ultimate reinforcing tool. In the student comment section, many agreed that this "once-in-a-lifetime experience" made them feel like a real scientist and able to collaborate on a real space mission (Figure 21). The pre- and post-survey was designed to evaluate if the balloon project improved the students' STEM dispositions.

The first section on the surveys – sampling the students' most and least anticipated high school classes – provided valuable information. The female students were most eager to study high school Fine Arts. No other subject had such a peak of interest as Fine Arts. Looking at the STEM categories, it can be seen that all of the students were more enthusiastic to study Science than Math, both before and after the ballooning project. Importantly, Science was the second most desired subject for the female students, following Fine Arts. The desire to study high school science and math increased for the females, increasing by 63 percent and 57 percent, respectively. As mentioned in the literature, females' planning to pursue science, especially as early as middle school, is a rewarding sign to both instructors and their futures.

The data from the male students exhibited more uniform patterns of high school subjects and did not display a spike in any one category as the females' did. The top three classes the males were eager to study before the NSB project were Health/PE, Fine Arts, and Math. After the NSB project, the male students were most eager to study Science, Health/PE, and Fine Arts. The NSB project positively impacted the male students' attitudes towards science, displaying a 46.7 percent increase. Also, science was the only subject to increase in the post-survey.

The females' least desirable high school class was math, before and after the NSB project. This reflects the research stated above in the literature review. One goal of the balloon project was to lessen the intimidation factor of math concepts and dissuade the females' from avoiding higher education math classes. Unfortunately, with the limited amount of time allocated to the project, the students retained their original feelings towards STEM subjects.

Male students highly anticipated English, both before and after the balloon project. This concludes that they are less inclined to writing, vocabulary, and spelling than computations and analytical thinking. Math and Science rankings actually increased in student apprehension, contrary to the project goals.

The second section of the pre- and post-surveys had the students express their STEM affinities towards school-, extracurricular- and home-related topics. Most of the students answered the survey questions with appropriate responses, but did not improve as expected, contrary to the hypothesis. The only concept that significantly improved after the balloon launch was their understanding of teamwork and collaboration.

It was vital for the students to collaborate in a team environment. The survey question, "*I Think Engineers Work Alone"* targeted their teamwork and critical thinking skills. Originally, students may have believed scientists require solitude in order to complete research, but had an increased understanding of teamwork after the NSB project.

When analyzing the students' responses to "*I Want to Go to UND*", it was necessary to consider circumstantial information. It was originally predicted that the students would produce *Strongly Agree* results, contrary to the actual *Neutral* results. They may be too young to start considering college choices.

It is important to note that Figures 15 and 16 –the students' most and least favorite ballooning activity –included *the chase* as a possible answer. Only 12 students participated on the balloon chase, which could have potential to bias the results and skew the distribution of student answers.

Student Attitudes

One monumental STEM conversation occurred with a male student while retrieving the balloons. When Borchardt and March walked across the landing site to reach Balloon 2, the students ran up ahead awaiting their return. The author stayed on the road in front of the school bus, when one male student started talking about how he wanted to study astronomy in the future and wanted advice regarding prerequisite classes. The student expressed how he felt intimidated to take advanced math, yet dreamed to study the cosmos. It was thrilling to learn that this thesis project was benefitting at least one student. The student was informed that he did not have to be the brightest student in the grade to study something he loved. Hard work, passion for the subject, and good study ethics would help him succeed.

All of the students were excited about the data analysis workshop. They viewed the graphs, charts, images, and videos. They were amazed at the burst video, which was shown frame-by-frame. All of the students, including Mr. Newman, expressed how amazed they were after seeing the results. Some student groups' sensors failed to perform, which made the students sad and discouraged. All of the groups were excited and eager to see the Space Banana, which was on display and was waiting for period four's analytical team.

Future Project Alterations

There are a few procedural alterations that are recommended for any future NSB projects. First, it is suggested that the overall length of the design and construction workshops be augmented. The student design and construction teams require a prolonged workshop in order to complete their payloads. Both teams need at least two full class periods to complete their project stress-free. This will benefit the overall payload structures, engineering concept investigation, team collaboration, and allow their critical thinking skills to develop. The original one-day-design and one-day-construction allotment was found insufficient. The students should not be required to stay before or after school in order to complete their projects.

The VMS launch provided designs and products for future middle school students, all of which can be used as teaching tools. Prior to the workshops, the instructor can use images of the 2013 VMS payloads to integrate into their lessons. Students would be able to consider concepts, such as drag and wind resistance, for their designs. They can be shown differences between various designs, all supporting different sensor functions. They could create a simple payload design, requiring less time for construction, or a complex design, requiring a lengthy amount of time.

The project's effectiveness may increase if the date of the launch is changed. The 2013 VMS launch was during a cold mid-November day. At 9:00 AM, the temperature was 34 degrees Fahrenheit; 48 degrees F at 10:00 AM; and by noon, the temperature had reached 52 degrees F (www.friendlyforecast.com, 2014). In the post-surveys, many students complained about filling the balloons outside for so long in such cold temperature. Instead of a late-fall launch, the students would benefit from a spring launch. Besides a much warmer environment, which would help facilitate any idle moments, the students would be launching at the end of the academic year, not the beginning. More opportunities would arise if teachers could amalgamate the entire year's lessons into the ultimate "capstone launch project". All eighth grade teachers could prepare the students for the launch, including history. With over eight months of forewarning, every teacher could form his or her own connections to the launch, with their preexisting lesson plan. Also, potentially all students would be able to attend the balloon chase. Acquiring early parent permission and finalizing bus logistics would alleviate last minute stress and chaos. Most importantly, other teachers, such as History and English teachers, would have a year's notice to arrange their syllabi.

Additionally, and potentially most imperative regarding safety, would be the coordination of the Minnesotan Hunting Season (Minnesota DNR, 2014). Depending on the landing location, an autumn launch may put students in a wooded area. Many hunters are out seeking deer in the same dense tree lines as the launch teams. As seen in Image 19, appropriate reflective attire was worn while retrieving the payloads, to ensure safety. If the launch occurs in the spring, deer season would have concluded and there would be minimal safety concerns.

A major disappointment occurred on the student chase vehicle. It was discovered at the last minute that the school bus' tracking system was missing a plug, unable to connect to the laptop. Unfortunately, none of the students got to experience a real balloon chase, complete with real-time GPS updates. Because it occurred on the 2013 launch, future chase teams will unlikely experience this problem. If a situation like this ever reoccurred in the future, it would be best to have a backup plan. They could switch the tracking gear from a secondary chase vehicle and place it in the student chase vehicle.

When continuing this project in the future, it is recommended to discuss special techniques with the students prior to the construction workshop. At such a young age, it is not expected that the students have already participated in technical operations. It was observed that many groups would cut their designs out of the Styrofoam boards from the center, instead of using the existing side as a straight edge (Appendix F; Image 9). This wastes valuable materials, impacting other groups who may need additional Styrofoam.

Newman observed this after it already happened and was able to teach them how to appropriately execute cuts for future events.

Future Research

The VMS project has initiated potential future collaborations with middle and high schools in Grand Forks. Aside from the pre-established NSBC launches, personal and grade-based balloon launches can exist using the methods discussed above. With this thesis-style project, teachers have the ability to integrate a NSB project into their curricula and enhance their lesson plans, rather than having to squeeze in an after-school project, dependent on student volunteers.

NDSGC received the student feedback comments, describing how to enhance a subsequent grade-wide NSB launch. At the same time that this study is being completed, NDSGC is concurrently preparing for another double NSB launch. They are implementing similar payload workshops with two new schools: South Middle School and Schroeder Middle School, both Grand Forks middle schools. These two launches will imitate the VMS launch, launching two balloons simultaneously. The top three payloads from these middle schools will be selected to fly onboard the NSBC balloons, competing in the statewide middle and high school competition. Since the VMS launch, all efforts to maintain the longevity of the balloon program have been successful.

CHAPTER VII

CONCLUSIONS

As mentioned in the *Are there Enough STEM Jobs in the U.S. Workforce* chapter of the Literature Review, individual careers in science and math may be a difficult journey for American students. Although STEM education is vitally important to maintain a leadership role in the global economy, the original hypothesis was proved false. After surveying the students before and after the dual-balloon launch, it was suggested that the engineering process, overall critical thinking skills, and team collaborations were the most valuable experiences for the eighth grade students. These students will have a higher chance of success in a competitive higher education career and professional life if they develop such skills at a young age. Critical thinking combines passion and creativity with discipline, conceptualizing, synthesizing, and evaluation.

The pre-launch workshops, specifically the design and construction sessions, were essential to introduce the students to the engineering process. For a hands-on activity, they were able to understand the scientific method from beginning to end. Rather than solely learning about this in a textbook, which they had previously covered, the eighth-graders were able to be a part of and conceptualize a real space mission. They were able to feel important while collaborating in a team environment and concurrently improving their self-efficiency, necessary for their future lives. There was one survey question that proved the NSB project positively impacted the students' understanding of team collaboration. They fully understand how engineers must cooperate and work with other peers.

Unfortunately, the goal of increasing the students' interests in STEM education and future careers was not obtained through this three-week project. The results from the pre- and post- surveys produced insignificant changes that could neither support nor deny an increased science or math appreciation. By moving the balloon launch to the end of the academic school year, the instructors will have the entirety of the year to teach STEM concepts while relating them to the future balloon launch. With such extended preparation, the students' level of STEM appreciation may rise when they realize the material they are learning has real world applications.

At some point in the students' lives, whether it's a job, sporting activity, or academia, they will all need to learn how to collaborate as a team, as they did with this project. Even though the NSB project does not teach students new material, this "Earth Science capstone project" is a great tool that harnesses previous knowledge and integrates that into their everyday lives. They must learn how to think critically and actively conceptualize life problems if the future American generation is to prosper.

APPENDICES

Appendix A

Acronyms

STEM……………….…………...…Science, Technology, Engineering, and Mathematics
NDSGC……………………………………….....North Dakota Space Grant Consortium
IRB…………………………….……………………..…Institutional Review Board
GPS………………………….…….…………..……….....Global Positioning System
GIS………………………………………………….Geographical Information Systems
HARP…………………………………………….....High Altitude Research Platform
ASU……………………………………………………..…..Arizona State University
APRS…………………………………….Automatic Packet/Position Reporting System
NCLB……………………………………………………….…No Child Left Behind
NGA……………………………………………….....National Governors Association
CCSSO……………………………………………..Council of Chief State School Offices
USDE…………………………………...…...…United States Department of Education
P21…………………………...……………………….Partnership for 21st Century Skills
Ph.D.……………………………………………...……………….Doctor of Philosophy
S&E……………………………………………………………Science and Engineering
FAA……………………………………………….....Federal Aviation Administration
FAR……………………………………………………….Federal Aviation Regulations
FCC…………………………………………......Federal Communications Commission
FSS………………………………………………………......…….Flight Service Station
PIREPS…………………………………………………………………….Pilot Reports
NOTAM……………………………………………………………...…..Notice to Airmen
NSBC……………………………........………...…….Near Space Balloon Competition

Appendix B

Consent and Assent Forms

THE UNIVERSITY OF NORTH DAKOTA
CONSENT TO PARTICIPATE IN RESEARCH

TITLE:	**Analyzing how effective hands-on learning and Science, Technology, Engineering, and Math (STEM) Education are with Near-Space Balloons**
PROJECT DIRECTOR:	**Marissa Saad**
EMAIL:	**marissa.saad@my.und.edu**
DEPARTMENT:	**Space Studies**

STATEMENT OF RESEARCH

To complete my master's thesis, I will be distributing a survey to the eighth-grade students of Valley Middle School to see how effective a hands-on Near-space balloon launch is with promoting science, technology, engineering, and math (STEM) education.

WHAT IS THE PURPOSE OF THIS STUDY?

You are invited to be in a research study regarding STEM education and the launch of two Near-space balloons. I will be distributing a paper survey before and after the balloon launch, with the collected data in order to determine if/how students' opinions change regarding STEM classes after the hands-on activity of launching a Near-space balloon. Your teacher will be integrating the launch into your science curriculum.

HOW MANY PEOPLE WILL PARTICIPATE?

Approximately 130 students will take part in this study during their science class at Valley Middle School.

HOW LONG WILL I BE IN THIS STUDY?

Your participation in the study will begin from when the first survey is distributed, through the balloon launch, and until the last survey is handed out. You will fill out the survey in your classroom. Each survey will take no more than five minutes.

WHAT WILL HAPPEN DURING THIS STUDY?
The survey will not have the student's name on it. It will only ask them about his or her preference to STEM subjects, and what they thought about the balloon launch. The survey will be handed out in class.

WHAT ARE THE RISKS OF THE STUDY?
There are no foreseeable risks to participating.

WHAT ARE THE BENEFITS OF THIS STUDY?
We hope to determine the effect, if any, of the Near-space ballooning experience on students' attitudes toward STEM education.

WILL I BE PAID FOR PARTICIPATING?
You will not be paid for being in this research study.

WHO IS FUNDING THE STUDY?
The North Dakota National Aeronautics and Space Administration (NASA) Space Grant Consortium.

CONFIDENTIALITY
The records of this study will be kept private to the extent permitted by law. In any report about this study that might be published, you will not be identified. Government agencies, the UND Research Development and Compliance office, and the University of North Dakota Institutional Review Board may review your study record.

Any information that is obtained in this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. If we write a report or article about this study, we will describe the study results in a summarized manner so that you cannot be identified

IS THIS STUDY VOLUNTARY?
Your participation is voluntary. You may choose not to participate or you may discontinue your participation at any time without penalty or loss of benefits to which you are otherwise entitled. Nonparticipation will not affect your current or future relationship with the University of North Dakota or Valley Middle School.

CONTACTS AND QUESTIONS?
The researcher conducting this study is Marissa Saad. If you have questions, concerns, or complaints about the research please contact her at ***marissa.saad@my.und.edu***. The researcher's advisors are Dr. Ron Fevig, reachable at rfevig@space.edu and Dr. Gail Ingwalson, reachable at gail.ingwalson@email.und.edu.

If you have questions regarding your rights as a research subject, you may contact The University of North Dakota Institutional Review Board at **(701) 777-4279**.

- You may also call this number about any problems, complaints, or concerns you have about this research study.
- You may also call this number if you cannot reach research staff, or you wish to talk with someone who is independent of the research team.
- General information about being a research subject can be found by clicking "Information for Research Participants" on the web site: http://und.edu/research/resources/human-subjects/research-participants.cfm

I give consent to be photographed during the balloon launch.

Please initial: ____ Yes _____ No

I give consent for my quotes to be used in the research; however I <u>will not</u> be identified.

Please initial: ____ Yes ____ No

Your signature indicates that this research study has been explained to you, that your questions have been answered, and that you agree to take part in this study.

Subjects Name: ____

___________________________________ ____________________
Signature of Subject Date

I have discussed the above points with the subject or, where appropriate, with the subject's legally authorized representative.

___________________________________ ____________________
Signature of Parent/Legal Guardian Date

Assent Form

Project Title: Using Near-Space Balloons to Analyze How Effective Hands-On Learning and STEM (Science, Technology, Engineering, Math) Education are for an Eighth-Grade North Dakota class.

Investigator: Marissa Saad (Graduate Student at Space Studies department at UND); Dr. Gail Ingwalson (Education Professor); Dr. Ron Fevig (Space Studies Professor)

We are doing a research study; a research study is a special way to find out about something. We are trying to find out if our near-space balloon launch is a good way to teach science and engineering concepts in middle school.

If you want to be in this study, we will ask you to do several things. You will receive a written survey that you will fill out. The survey will not have your name on it. After we launched our near-space balloons, we will hand out another survey. We will compare these pre- and post- surveys to see how students' opinions change regarding STEM classes.

We want to tell you that there are no physical risks if you are in this study.

Not everyone who is in this study will benefit. A benefit means that something good happens to you. We don't know if you will benefit. But we hope to learn something that will help other people some day.

When we are done with the study, we will write a report about what we found out. We will not use your name in the report. You do not have to be in this study. It is up to you. If you want to be in the study, but change your mind later, you can stop being in the study.

If you do not want to be in this study, we will tell you about the other things we can do for you.

If you want to be in this study, please sign your name.

____

Your name (printing is OK) Date

I certify that this study and the procedures involved have been explained in terms the child could understand and that he/she freely assented to participate in this study.

____

Signature of Person Obtaining Assent Date

Appendix C

Pre-Survey

NEAR-SPACE BALLOONING PRE-SURVEY

To help us determine how effective the near-space balloon experience will be, please complete this anonymous survey and return it to Mr. Newman. Your participation and honesty is appreciated. (STEM = Science, Technology, Engineering, Mathematics)

Ethnicity	**African American**	**Asian**	**Hispanic**	**Native American**	**White**	**Other**
Gender	**Male**	**Female**				
Does a parent/guardian work in a STEM field?	**Yes**	**No**				
Did you play with building toys when you were younger? (ex. Lego's, Lincoln Logs, K'nex, etc.)	**Yes**	**No**				
Have you seen a Near-space balloon launch before?	**Yes**	**No**				
Have you ever launched model rockets before?	**Yes**	**No**				

Please circle **up to 2** of the following for each statement:				
In high school, I am *most* looking forward to studying:	Fine Arts (Theatre, Music, Art)	English	Mathematics	Science (Geology, Physiology, Anatomy, Physics, Biology)
	Social Studies	Health/Physical Education	Foreign Language	Business/Marketing
In high school, I am *least* looking forward to studying:	Fine Arts (Theatre, Music, Art)	English	Mathematics	Science (Geology, Physiology, Anatomy, Physics, Biology)
	Social Studies	Health/Physical Education	Foreign Language	Business/Marketing

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Please check off the appropriate box.					
I plan on joining a science-related extra curricular activity in high school.					
I think astronomy is interesting.					
I believe engineers complete their work alone.					
If I want to pursue a STEM career, I have to work solely for NASA.					
I plan on going to college after I finish high school.					
If college is in your future plans, how interested are you in attending the University of North Dakota?					
I hope to get a job in a science field when I'm older.					
I have a specific career in mind.					

Post-Survey

NEAR-SPACE BALLOONING POST-SURVEY

To help us determine how effective the near-space balloon experience will be, please complete this anonymous survey and return it to Mr. Newman. Your participation and honesty is appreciated. (STEM = Science, Technology, Engineering, Mathematics)

Try to fill out this top section the same way you did on the first survey.

Ethnicity	**African American**	**Asian**	**Hispanic**	**Native American**	**White**	**Other**
Gender	**Male**	**Female**				
Does a parent/guardian work in a STEM field?	**Yes**	**No**				
Did you play with building toys when you were younger? (Lego's, Lincoln Logs, K'nex, etc.)	**Yes**	**No**				
Have you ever launched model rockets before?	**Yes**	**No**				

Please circle **up to 2** of the following for each statement:				
In high school, I am *most* looking forward to studying:	Fine Arts (Theatre, Music, Art)	English	Mathematics	Science (Geology, Physiology, Anatomy, Physics, Biology)
	Social Studies	Health/Physical Education	Foreign Language	Business/Marketing
In high school, I am *least* looking forward to studying:	Fine Arts (Theatre, Music, Art)	English	Mathematics	Science (Geology, Physiology, Anatomy, Physics, Biology)
	Social Studies	Health/Physical Education	Foreign Language	Business/Marketing
My *favorite* part of the ballooning experience was:	Creating the design for the payload	Building the payload	Filling up and launching the balloon	The balloon chase
My *least favorite* part of the ballooning experience was:	Creating the design for the payload	Building the payload	Filling up and launching the balloon	The balloon chase

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Please check off the appropriate box.					
The ballooning experience was educational.					
The ballooning experience was fun.					
The ballooning experience was inspiring.					
Watching the instructors helped me understand how the engineering process works.					
Working with my peers showed me what it's like to be an engineer.					
I plan on joining an extra-curricular activity in high school.					
I think astronomy is interesting.					
I believe engineers complete their work alone.					
I plan on going to college after I finish high school.					
If college is in your future plans, how interested are you in attending the University of North Dakota?					
I hope to get a job in a science field when I'm older.					
I have a specific career in mind.					
I would recommend this ballooning experience to other students.					
I would enjoy attending another balloon launch (either with my school or watching UND's local launches).					
I would recommend UND's local balloon launch to family and friends.					

What scientific method role did you perform? Please circle one.

Hypothesis Design Construction Conclusion Final Report

Did you ride in the school bus and go on the balloon chase? Yes No

In one sentence, please describe how you felt about the entire ballooning experience:
____-
____-
____

In one sentence, please mention something you would like to have changed for next year's students:
____-
____
____

Appendix D
Student Payloads

After the balloon chase, the graduate students examined both payload trains in the Space Studies department. The containers were structurally sound; everything was intact. All tracking gear was viable, minus the radio antennas that broke during impact. The PowerShot cameras were inspected, but unfortunately contained no images. Upon analysis, only three were operational during flight and produced results (Figure 23). *Relative Humidity* and *Pressure* were the best sensors for data displays. Despite the malfunctioning sensors, the students still completed their science reports. The students understood that a real science mission might not always cooperate, especially while using technology. Their research team, while creating the hypothesis, knew what data they should have received, and were able to elaborate on those data.

GoPro Video Camera

One class launched a Hero Naked GoPro video camera. The camera was set to shoot 2.5 hours of 720p High Definition video with a 170-degree field of view. The students designed their payload to house the camera facing upwards, towards the zenith. The camera was successful, capturing the ascent, balloon burst, and descent. The Earth can be seen throughout the entirety of the video, as the payload train oscillated the camera back and forth.

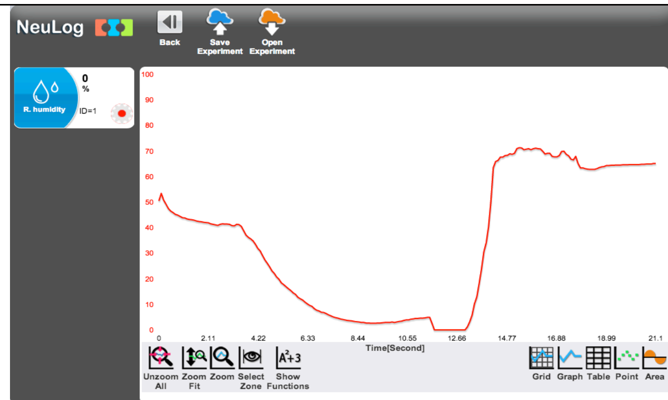
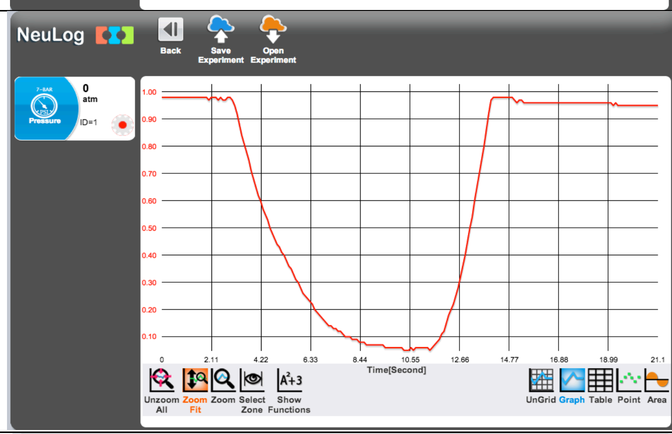
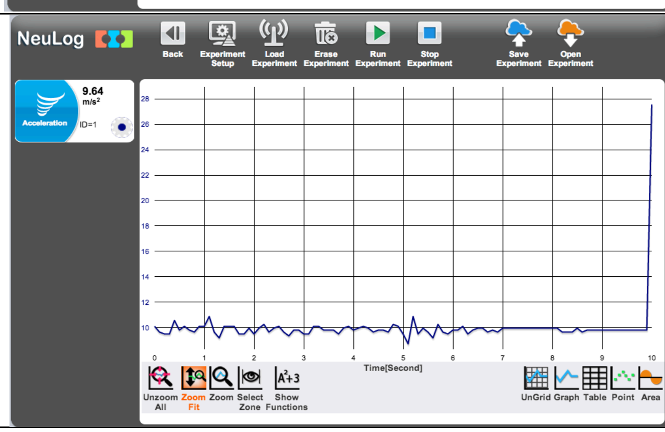
NeuLog Sensor	Student graph analysis
Relative Humidity	
Pressure	
Acceleration	

Figure 22: Student NeuLog Sensor Results

PowerShot S70 Cameras

The two PowerShot S70 cameras, one infrared and one visible, were positioned in the payloads to capture images at 1-minute intervals. Each camera had a major design flaw that hindered the students' experiments. The on and off mechanism was a sliding front door that covered the camera lens. When the cameras were on and functioning, the slightest nudge or pressure on the door would cause the camera to automatically turn off. After both cameras were secured in the payload chain, it was deduced that the PowerShots shut down before the balloons ever took flight.

Space Banana Experiment

The eighth-grade students could not put anything they wanted into a payload container without creating a scientific hypothesis and procedure to back it up. A class formulated another experiment on their own, called the "Space Banana Experiment". The students created a sound scientific hypothesis, set up a control banana on the ground, and earned payload space for this secondary experiment.

The students involved with the experiment obtained two yellow bananas at the supermarket that were attached in the same banana bundle, to ensure accuracy. One banana was placed in the payload container, and the other banana was left with the students on the ground, as the control group. The students observed the bananas before and after the balloon launch.

Post-launch, the "Space Banana" returned intact. It was covered in condensation, feeling slimy and slippery to the touch. It was considerably colder than the control banana, having voyaged into the sub-zero temperatures of the atmosphere. Very rapidly, the Space Banana turned a dark brown and black color. During the next class period after the launch, Mr. Newman had the students complete their analysis by proctoring a taste-testing session. The students took a bite of the control banana and subsequently the Space Banana. Many students were shying away from tasting the Space Banana due to its dark, rotten color. Newman informed the students that they are the scientists who have to follow through with their science; that science is fun, yet not always appetizing.

Image 1: Space Banana Experiment

All of the students on the Space Banana team participated in taste-testing both bananas. They enjoyed the control banana, most likely because it was only a few days old. The students said the Space Banana tasted very sour and mushy, causing almost all of the students to run to the classroom sink, spitting the banana out and washing out their mouths. Some students ate more than one bite, either showing off for their friends or actually enjoying the taste. One thing was for certain: no one could eat the Space Banana without forming a comical facial expression (Saad, 2013).

Appendix E

Further Information Regarding Near-Space Ballooning

American Radio Relay League (AARL): http://www.arrl.org/ham-radio-licenses

AirGas - http://www.airgas.com/home.aspx

Balloon Track: www.eoss.org/wbaltrak/

GPS Visualizer: www.gpsvisualizer.com

Ham Radio Outlet - http://www.hamradio.com/

Kaymont Balloons http://kaymontballoons.com/

Kenwood (primary tracking systems): http://www.kenwoodusa.com/

Near-Space Ballooning Competition. http://ndspacegrant.und.edu/pre-college/payload_competition.aspx

NeuLog Sensors: http://www.neulog.com/

SPOT GPS Tracker: www.findmespot.com

Appendix F

NSB Project Images

Image 2: Introduction Workshop

October 31, 2013

Image 3: Introduction Workshop

Image 4: Introduction Workshop - Selecting Sensors

Image 5: Design Team Calculating Dimensions

November 5, 2013

Image 6: Construction Workshop

Image 7: Construction Workshop

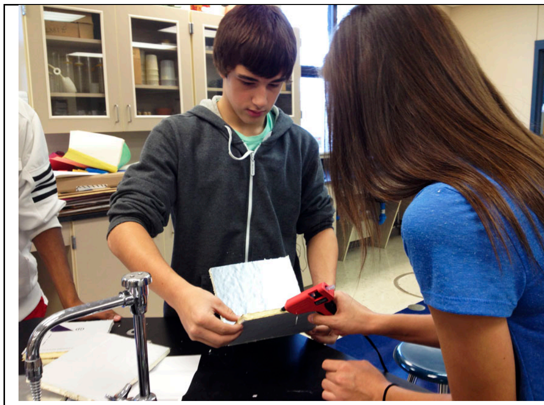


Image 8: Construction Workshop

Image 9: Construction Workshop

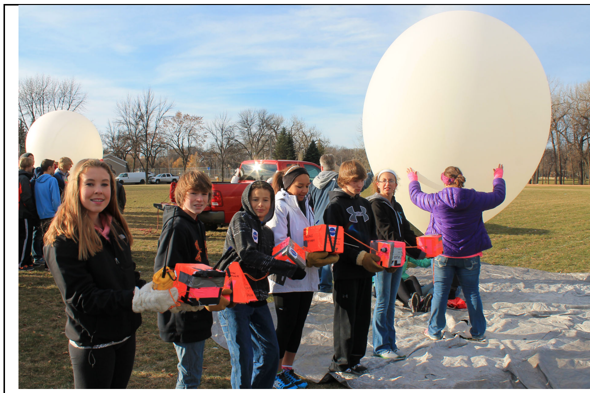
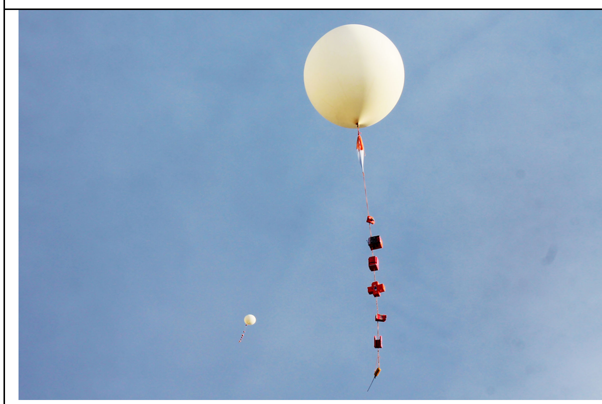
Image 10: Construction Workshop

Image 11: Dr. Fevig Briefs the Students About the Balloon

November 13, 2013

Image 12: Students Help Secure the Balloon Before Launch

Image 13: Securing Both Balloons (Moments Before Launch)

 Image 14: Students Hold Balloon 1 Payload Train	 Image 15: Students Hold Balloon 2 Payload Train
 Image 16: Both Balloons Ascending	 Image 17: Students with the Payload Train after a Successful Recovery
 Image 18: Graduate Student Brian Badders Retrieves Balloon 1	 Image 19: Graduate Student Josh Borchardt Retrieves Balloon 2

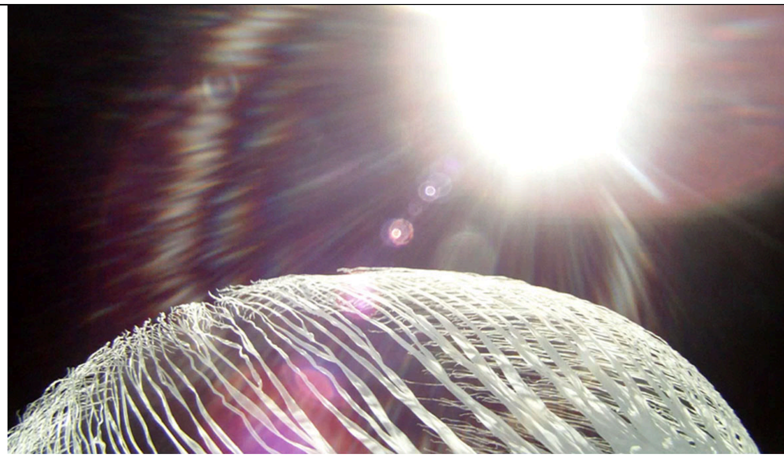


Image 20: Balloon Burst

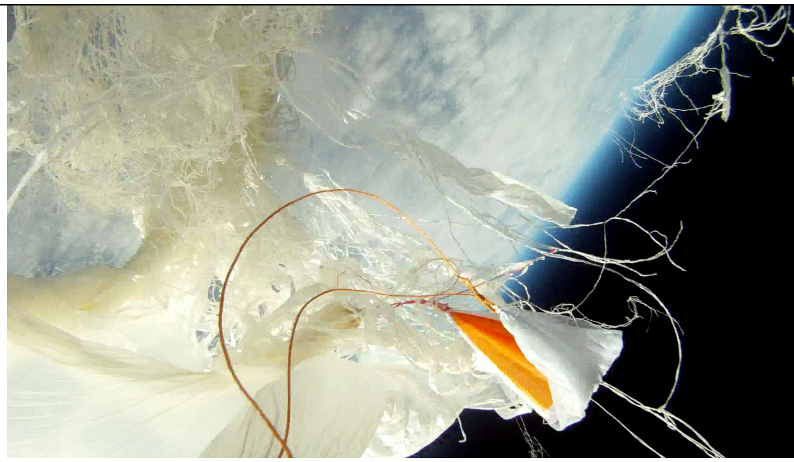


Image 21: Balloon Burst, Parachute, Earth, and Atmosphere


Image 22: View from 102,000 Feet

Table 15: Specifications from Balloon Flight

	Balloon 1	**Balloon 2**
Liftoff Time*	9:42 AM	9:42 AM
Burst Time*	11:34 AM	11:07 AM
Landing Time*	12:05 PM	11:32 AM
Maximum Altitude	102,500 Feet (31.2 km)	102,050 Feet (31.1 km)
Experiments on Payload Train	Period 6 Magnetic Field Period 4 Carbon Dioxide Period 4 Accelerometer and Space Banana Period 6 Temperature Period 7 Oxygen and Visible Light Camera Period 5 IR Camera	Period 5 GoPro Video Camera Period 2 UVB Sensor Period 2 Pressure Period 7 Accelerometer Period 3 Wide Range Temperature Period 3 Humidity
Landing Location	47.71698, -95.33484	47.78915, -95.57443

*All reported times are Central Standard Time (CST)

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