Impact of the 2016 Global Space Balloon Challenge on Student Attitudes towards Science and their Perceptions of how Science is Conducted

by

Andrea Misner

Thesis submitted to the Faculty of Graduate Studies of

The University of Manitoba

in partial fulfillment of the requirements for the degree of

MASTER OF EDUCATION

Department of Curriculum, Teaching and Learning

University of Manitoba

Winnipeg, Manitoba, Canada

Abstract

This thesis is a qualitative case study of Maples Collegiate high school students who participated in the 2016 Global Space Balloon Challenge (GSBC). The case study explored the impact of the GSBC on students' attitude towards science and understanding of how science is conducted. The literature review showed there is little research on STEM-based learning projects at the high school level and the impact of these activities on students' views of science. The findings suggest the four students interviewed experienced a positive impact on their attitude towards science and understanding of how science is carried out in the scientific community. Limitations to the research include the number of participants and all four participating students having a positive predisposition to science. This opens the door for future research into how other STEM-based learning activities impact students' views of science particularly when students do not have an interest in science.

Keywords: STEM-based learning, secondary education, out of school time programs, attitude to science, Global Space Balloon Challenge

Acknowledgements

I would like to acknowledge the following individuals for their support and assistance through my research: my advisor Dr. Barbara McMillian, members of my thesis committee Dr. Lilian Pozzer and Dr. Merli Tamtik, Rob Streamer and the members of MAPT, my co-workers at Maples Collegiate who participated in the Global Space Balloon Challenge, Melanie Richard for her support with grant writing and inspiration to begin this journey, and Kevin Mogk for transcribing the interviews. Without all of you, this endeavour would have never have come to fruition.

Dedication

For Rob Striemer, who first started this journey with the Manitoba association of physics teachers (MAPT), and for Elizabeth Schachter, may your enthusiasm for learning and teaching live on within us.

Table of Content

List of Tables

List of Figures

Chapter One

The balloon slipped off the home-made PVC pipe filling tube attached to the helium tank and launched into the air far out of sight. Our jaws dropped, and our hearts sank. The students in my Grade 12 physics class at Maples Collegiate were competing in the Global Space Balloon Challenge (GSBC), and we had just lost our balloon to the cold and unforgiving wind. Surrounded by students and teachers from four other Manitoba high schools in a soccer field at Carmen Collegiate high school, we thought we were out of the challenge.

This Masters of Education thesis presents the results of a qualitative research project focused on high school students' experiences in the 2016 Global Space Balloon Challenge, and explores the impact of this STEM based project on students' attitudes towards science and understanding of how science is conducted.

MAPT's Participation in the Global Space Balloon Challenge

Participating in the GSBC began with the teacher group known as the Manitoba Association of Physics Teachers (MAPT). MAPT has been promoting excellence in physics education since the early nineties. Robert Striemer, a physics teacher from Shaftesbury High School in Winnipeg, Manitoba, had been involved with high altitude science with the launching of weather balloons, as well as amateur radio, for approximately seven years prior to brining the idea to MAPT in 2014. Striemer, at the time, was considering retirement and wanted to pass along what he and his students had learned by sharing their recent GSBC experience with other teachers and students. All of the physics teachers at the meeting with Streimer were fascinated with the project. We wanted the challenge for ourselves and our students. Right from the beginning, the continuation of this project locally was a collaboration among the MAPT teachers.

MAPT members discussed what was involved with such a project. These conversations focused on materials, the cost of the required materials, and the student experience. We realized that if we were going to be able to participate in the GSBC, we would need to convince either our school divisions or other educational institutions, such as the Science Teachers Association of Manitoba, that this project was worth funding at a cost of approximately one thousand dollars per school group.

The Global Space Balloon Challenge

The GSBC began as a collaboration between engineering students at Stanford University, the University of Michigan, and the Massachusetts Institute of Technology (Logan, 2014). The launch of the first GSBC in 2014 involved 87 teams in 29 countries (Logan, 2014). The GSBC of April 2017, had 466 registered teams in 58 countries. Of these teams, 33 were Canadian and of the Canadian teams 11 are located in Manitoba (Global Space Balloon Challenge, n.d.).

Participating in the GSBC involves a group of students working together to build and launch a payload using a 1200 g weather balloon. The main goal of the project is to successfully build the payload as a team, launch it into the upper atmosphere (about 30 km), and retrieve it to gather the data collected by the equipment carried as payload cargo. The building of the payload is generally separated into tasks that are shared by smaller groups of students, or sub-teams, with specific responsibilities (e.g., the experiment team, the payload team and the camera team). The payload itself cannot be more than 1500 g in mass. To gather data, the payload is equipped with three Mobius Action Cameras that are to face in different directions. These cameras capture the aerial ascent of the payload as well as the side view, the weather balloon expanding above with increased altitude and, at 30 km, the curvature of the Earth (Figure 1, page 3).

The payload also carries Arduino sensors to record temperature, pressure, and altitude at the various levels in the atmosphere. Further, the payload is equipped with an automatic packet reporting system (APRS), which is a tracking system. This system broadcasts at 144-390 MHz and sends out a packet of information, with latitude and longitude coordinates, that anyone can track online using the aprs.fi Google website and typing in my HAM radio call sign V4ANGC-6. If everything is launched successfully, the students will have the ability to track their balloon in real time using the aprs.fi website. Once we have retrieved the payload we can download the data packet information from the Google website and see exactly where our balloon has gone (Figure 2, page 4).

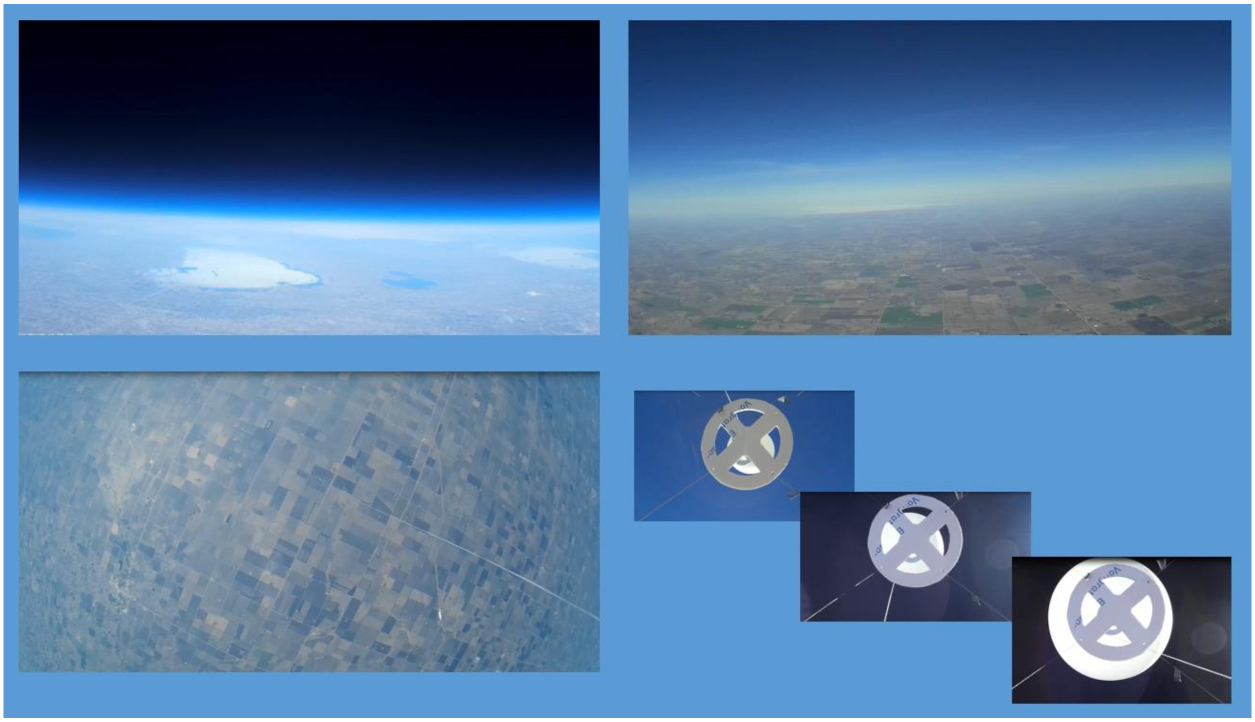

Figure 1. Three images of Manitoba from approximately 30 km above Earth's surface (upper row and lower left) and the weather balloon ascending and expanding as pressure around it decreases (lower right).

Initially the project learning goals for the students were to be able to communicate and work together. They must be able to collaborate, coordinate their different tasks, and think creatively and critically to construct a payload within a specific mass restriction. Members of each sub-team are responsible for their task but must also be in constant communication with the members of the other sub-teams to bring everything together in one payload. Moreover, on the day of the launch the students must be able to think on their feet to make quick decisions in solving untold problems as they occur. It is anticipated the students will see that such learning experiences do not always work smoothly and require good problem-solving and communication skills.

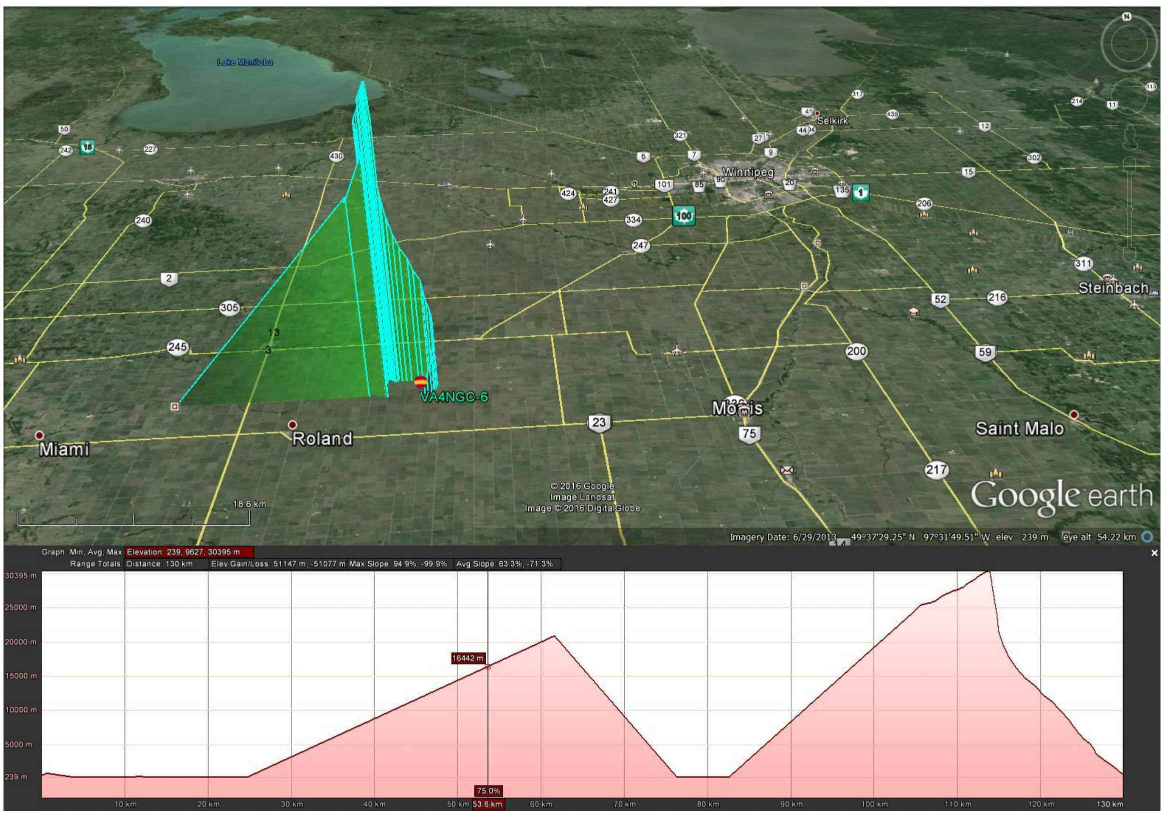

Figure 2. Image showing the weather balloon and payload changing altitude over Manitoba.

The 2015 Maples Collegiate Global Space Balloon Challenge

To ensure I had a group of enthusiastic and committed students, I decided to incorporate the challenge in my Grade 12 Physics 40S class. I wrote a proposal that outlined what the GBSC was about and how much it was likely to cost and presented it to my principal. Once I showed how the project was connected to the Physics 40S curriculum, my principal granted funding for the project.

The first step I took was to get the class to work together as a team, not as individuals. The students came up with a team name and called themselves, “The Net Force,” which in physics means the sum of all forces acting on an object. They thought this team name was appropriate, because the class was acting as the sum of their efforts to participate in the GSBC. Developing a team name not only heightened the excitement about participating in the Global Space Balloon Challenge, but it also motivated the students to work together in a more collaborative fashion.

The second step for me as the teacher and project supervisor was to break down the tasks to be carried out by the students in order for their participation in the challenge to be successful. This meant grouping the students into small teams to coordinate the building of the payload. I decided to create teams of students responsible for each task. These teams were named the “Payload Building Team,” “Experiment Team,” “Photography and Videography Team,” and “Communications and Media Team.” I found this worked well to focus small groups of students on a specific task. Partway into the process, however, I discovered that in a class of twenty-five students not all students were equally engaged and even smaller groupings would have worked better.

As the teacher-supervisor, I was responsible for ordering all the materials needed for the GSBC, creating permission forms, coordinating the student teams, and communicating with

MAPT teachers who also had students participating in the GSBC. Our sister high school, Garden City Collegiate, was a huge help in sharing payload construction material. While this was happening, the MAPT teachers were meeting once a month to discuss workshops that could be held during the school year to support science teachers in their teaching of physics. However, most of our conversations focused on the GBSC and how to obtain helium and fill the weather balloon and how we would use the APRS tracking system with each weather balloon.

Using the APRS tracking system in the payload once it has been launched can be a real obstacle. To release a weather balloon, you need to have an APRS tracking system in the payload to know where your balloon is in real time. However, you need a HAM radio licence and call sign to do this. Fortunately for us, Robert Striemer had started an amateur radio club at his school. The radio club had enough radio licences and call signs for all five of the weather balloons to be used in the launch. Later, my colleagues and I discovered just how much work goes into obtaining a basic radio licence. When we launched the Maples Collegiate payload in 2015 I did not have my HAM radio licence, but I did obtain it for the 2016 GSBC launch.

One of the challenges of the GSBC project is finding a suitable place to launch the balloons. The location must be suitable in terms of vegetation, weather, and wind speed, and there must be access to lavatories. Due to the weather patterns, the location must be narrowed down to three sites seventy-two hours before the scheduled launch. Only at the forty-eight hour mark, using online weather balloon prediction software, can you officially make the decision about the launch location.

There are many safety issues to consider, as well. In 2015, one of the supervisors of the participating Winnipeg teams was required to contact Nav-Canada that operates Canada’s civil air navigation system to inform them of the launch of five 1200 g weather balloons. Also, these weather balloons are not to drift over airports, cross national borders, or land in a crowded public space. We narrowed down our launch location to the field behind Carmen Collegiate High School in Carmen, Manitoba.

The day of the launch, April 24, 2015, was a cool, over cast and windy day. Everything was going well. Nine of the twenty-eight students in my senior physics class could travel to the launch site due to the responsibilities and restrictions nineteen students had that day. We went to work setting up our equipment and laying out the trap lines for the balloon. Because the class had written out the step-by-step procedures to follow prior to the physical launching of the balloon, this set-up was like a NASA launch checklist. Two on-site students had the job of checking off each task as it was completed. We learned that no matter how prepared you are, things do not go according to plan: Everything that could go wrong, did go wrong.

We quickly realized that our GPS was not putting out a signal, and that the parachute lines, attached to fishing swivels glued on top of the payload, had broken off. The students drew together and fixed these issues with assistance from me and other teacher volunteers. Then, just as the students started to fill up the weather balloon with helium, we discovered a leak in our line to the helium tank. Duct tape came to the rescue and stopped the leak. When the balloon was almost filled with helium gas, the wind pushed the balloon over and ripped it from my co-worker’s hands. The one and only balloon we had was gone, leaving us with an empty helium tank. The experienced students and teachers from Shaftesbury High School came to our rescue, with a second balloon. They had once lost a balloon in a similar manner and arrived in Carmen with a back-up balloon.

The nine students from Maples Collegiate did not lose all hope and give up, but drew together to continue their participation in the GSBC. Other schools participating in the challenge brought over the remaining helium in their tanks for us to use. It was just enough to fill the balloon we had been given from Shaftsbury. Tensions were high and stress had begun to set in with this “second chance.” We could not afford to lose the second balloon. Our school was the last to launch, but launch we did. Released stress and joy erupted in screams of excitement from Maples Collegiate students and teachers as our balloon took off into the sky. Now that this nerve-racking launching process was over, we had to jump back into our vehicles and track the balloon with its payload.

The entire tracking process took approximately two and one-half hours. These hours were taken up driving all over the back roads of southern Manitoba and discovering that our cell phone signals did not cover this entire area. Again, with the help of Shaftesbury High School and the radio licences of their teachers, the students could track down the location of their payload and obtain the video data. It was a very long day, but in the end students had a once in a lifetime experience in seeing how science and technology function together in the world outside of the classroom. Moreover, the students had the opportunity to work as a team to solve problems on the spot as the day developed. In the classroom, the typical science lab exercises have procedures that have been tested many times before. The outcomes are already known to the teacher and many are known to the students when the learning experiences are confirmation exercises. I couldn’t help but wonder what impact the experiences in the GSBC were having on my students’ attitudes towards science, particularly the intersection of physics and technology.

The 2016 Maples Collegiate Global Space Balloon Challenge

When the 2015-2016 school year began, my two co-workers, also science teachers at Maples Collegiate, and I started a lunch-hour science club for students in Grades 9 through 12. The club started off well, but by November the students were losing interest in the experiences we were providing. It was clear we needed a new direction for the science club before students began to drop out. At the time, members of the Manitoba Association of Physics Teachers were starting to talk about getting involved again with the Global Space Balloon Challenge. To breathe new life into the Maples Collegiate Science Club, I suggested getting the Science Club involved with the GSBC. My co-workers agreed, and I got to work writing grants to cover the costs of participating. Fortunately, Garden City Collegiate had filmed and prepared a short video of the April 24, 2015 launch day with images of the students working together, as well as the images and video that were taken from the video cameras in the weather balloon's payload. This video of the launch and images from high in the atmosphere caught the attention of the Seven Oaks School Division administrators, and they awarded Maples Collegiate and Garden City Collegiate with $2500 each for the project. I was also successful in obtaining a one-thousand-dollar grant from the Science Teachers Association of Manitoba (STAM). The Science Club now had a total of $3500 to spend on everything related to the project.

Maples Collegiate is strong in the performing arts such as band, choir, film, broadcasting, dance and the fine arts. In fact, many of these sorts of courses are taught during the period for lunch. As a result, the students involved in the Science Club occasionally found attending the club meetings a challenge. Fortunately, we had thirteen dedicated students with a core of four students who directed all others in the Science Club and kept them focused on the various tasks that needed to be accomplished.

With the grant funding, the group decided upon the equipment to buy. The students created a name and logo. As with the physics students the previous year, this collaborative decision-making brought the students together as a team. I began to see that the students worked more independently as a group and were learning things that the 2015 group had not. For example, the students wanted to use Arduino software to record the altitude, temperature and pressure of the outside atmosphere. I knew nothing about Arduino software and couldn't guide the students in its use. This was difficult for me as an educator. I had to let go and not be anxious or agitated about knowing less than the students. By the time of the launch, the students had outreached Maples Collegiate teachers who where experienced in programming.

Following the practice of the previous year, the students were guided into small groups with specific tasks (e.g., the payload building team). I discovered that this method initially worked well, but as time went on certain students had commitments and could not make all of the out-of-school time meetings. Suddenly other students jumped in and finished the task or started new ones that needed to be done. Instead of a large class of physics students working on this project during the time the course was scheduled, we had a smaller group of students sporadically working at lunch hour, and sometimes after school, to finish putting the GSBC project together. Having a smaller group of students worked well to ensure that all students had a role in the project and felt a part of the Maples Collegiate team.

On the day of the launch, we ended up in the soccer field at Morden Collegiate High School in Morden, Manitoba. Thirteen students from Maples Collegiate attended the launch day. They worked extremely well together to set everything up to prepare the payload for launch. In contrast with the previous year, I felt these students were more prepared and confident that things would go smoothly. In science and STEM-based projects, however, things do not always go as planned.

The count down was on. Three. Two. One. Our payload took off, ascended a few meters then quickly descended and crashed. This was devastating. There was insufficient helium in the balloon to lift the payload. It is a very tricky procedure to undo the balloon's duct taped and zipped end, and attempt to add more helium gas. Again, the students united to solve the problem quickly. Something else I had observed prior to the launch was the students walking on to the soccer field with the mentality that this was some sort of competition between schools. As their payload crashed to the ground, we needed support, communication, and collaboration to get the payload back into the air. Students from all the participating schools ran in to help, and only by working together with other teams could the Maples Collegiate team achieve its goals. Even though it was a stressful experience to not have our payload launch when we thought it should, I believe the students learned so much more through this shared problem-solving. In the end the Maples team of students felt they were a part of something larger than themselves; something unique.

Working with students outside of the courses I was teaching provided a different experience from hosting the project within my Physics 40S class. A smaller group of thirteen students worked better together than a larger group, and the small team of students seemed more motivated. Further, it was each student's choice to join the Maples Collegiate Science Club and put his/her personal time into the project, compared to the previous year's Physics 40S class where it was not a student's choice to participate in the GSBC. Throughout my time working with students in the Science Club, I continued to wonder how their experiences in the club and working on the GSBC project were affecting their perspectives of science and the interplay of science and technology.

Purpose and Significance of the Study

The purpose of my research was to explore Maples Collegiate Science Club members' changes in attitude to science and perception of science following their participation in the 2016 GSBC. My research questions are as follows; How does the 2016 GSBC impact students' attitudes towards science? How does the 2016 GSBC impact students' perceptions of how science is conducted?

Many labs that we do in the classroom have pre-written procedures and outcomes known to both teachers and students. Owing to the number of learning objectives in curriculum documents and the time scheduled for science, science labs rarely provide open-ended questions or time for student generated questions and inquiries. There is little if any time for critical and creative thought. Students, going through most laboratory exercises, do not have the opportunity to experience how science functions in the world outside of the classroom. I believe this is where science clubs held outside of class time, which include a variety of projects, can assist in filling a need for students experiencing first-hand explorations that connect skills such as critical thinking, collaboration, creativity, and problem solving. As will be shown in Chapter 2, there is little research at the high school level reporting on after-school and out-of-school time focused on STEM projects. Furthermore, few of these studies utilize qualitative methods, such as interviews and focus groups.

Introducing students to more complex projects offers the opportunity to draw upon a variety of skills and integrate concepts and topics from several different disciplines. Students in the GBSC, for example, learned how to build, solder, program, and collaborate as a team. The 2016 GSBC connected physics, chemistry, computer science, and technology, while further developing students' ability to communicate, to think critically, and to be creative in a team. To a degree, this mimics what occurs in certain laboratories and field projects where scientists have the opportunity to work together to achieve a specific goal. In other ways, the GSBC, although a challenge, acts as a competition for the students with the other schools given that students rarely have the occasion to work with students attending schools within the same or different school divisions. It is only on the day of the launch that they have the opportunity to meet and interact with peers attending different schools. This aspect of competition is also seen in the scientific world when economics (i.e., attaining funding) and discovery (e.g., new evidence and/or explanation) are at play between groups of scientists. One can't help but think that the GSBC experience could have consequences on students' attitude to science and perceptions of science and technology. This is what I aimed to explore in this study.

In Chapter 2, I begin with a review of the literature on afterschool programs and out-of-school time programs (OST). This is followed with a review of published research on students' attitudes towards science, including STEM (Science, Technology, Engineering and Mathematics), what these attitudes are, and how these attitudes are elicited by researchers. I end with a review of the literature focused on students' perceptions of how science is conducted and how these perceptions are elicited. The theoretical framework of the study is outlined in Chapter 3. In Chapter 3 I also describe the research methodology and method used to carry out the study, and set forth the two research questions. In Chapter 4, I present the interview data. Chapter 5 is focused on the findings of the study. In Chapter 6, I draw conclusions from the findings in the context of the current published literature, state the limitations of the study, and offer suggestions for future research focused on issues and practices built upon or identified in the study.

Chapter Two - Literature Review

To understand how projects like the Global Space Balloon Challenge influence students' attitudes towards science and perceptions of science, I first explore the educational literature focused on after-school and out-of-school time (OST) programs and the general impact they have on students' education and lives. I then examine in greater detail the literature associated with students' attitudes toward science, including STEM, and review how these attitudes are assessed. Finally, to gain a better understanding of students' perceptions of scientific practices, I explore student views of the nature of science (NOS) and how these views are made known to researchers.

After-school and Out of School Time Programs

An after-school program is defined as the time students spend outside of the classroom for further educational purposes after the school day has ended (Schwartz & Noam, 2016). In several published case studies, the definition has been expanded to include out-of-school time (OST): the time students spend before and after-school as well as programs run during the summer months (Krishnamurthi, Ballard, & Noam, 2014; Schwartz & Noam, 2016). Shah and Noam (2013) define OST programs as:

> Programs that offer activities that may or may not align with school curricula, that focus on youth development and enriching learning activities, and that can take place in a school setting, local community center or museum, on weekdays, weekends, or during the summer (as cited in Suter, 2016, p. 664).

The Maples Science Club fits both the definition of after-school programs and OST programs outlined by Shah and Noam (2013) and Schwartz and Noam (2016). The Maples Collegiate Science Club meets during lunch hour, which is set outside of formal education time and in 2016, the club was focused on a unique hands-on activity, the Global Space Balloon Challenge project, that primarily occurred during out-of-school time.

North American after-school programs have occurred since the late 1800s when the economic need for child labour decreased and formal education/schooling encountered greater demand (Halpern, 2002). Over the subsequent decades after-school programs were gradually developed to assist low-income families. The programs were designed to keep children out of trouble and off the streets during a time of day when most issues involving troubled youth occurred (Halpern, 2002). During the past forty years, after-school programs shifted to include both low-income and middle-class family support (Halpern, 2002). The aims of these programs were to positively influence personal development and to promote social and emotional growth (Krishnamurthi et al., 2014). Since 2000, there has been an increase in the number of OST programs, both in the United States and other post-industrial nations, that have focused their curriculum on science or the integration of Science, Technology, Engineering and Mathematics (STEM) (Krishnamurthi et al., 2014; Schwartz & Noam, 2016). There are two reasons for this; one utilizes a citizenship argument, and one uses an economic argument. It's obvious that the world of the 21st century is changing and that the challenges facing the human population are complex. In order to make decisions on issues such as climate change, patents on genetically modified organisms, technological innovations, groundwater management, and the loss of biodiversity, it is said that citizens require a greater level of science and STEM literacy. On the other hand, in many other countries, economic competitiveness demands innovation and, thus, requires a healthy number of science and technologically literate employees in the workforce (Schwartz & Noam, 2016). According to Krishnamurthi et al. (2014), "more and more jobs require STEM, and there is a great concern that without access to adequate educational experiences, large segments of the population will be unable to participate effectively in the modern workplace" (p. 3).

In response to the economic argument, the workforce in the United States is now requiring more employees with STEM knowledge and skills (Krishnamurthi et al., 2014). During the past ten years, the United States has been out-performed in science and mathematics. American governments at federal and state levels and corporations and industries in the United States are advocating for afterschool and OST programs focused on these disciplines (Krishnamurthi et al., 2014; Schwartz & Noam, 2016). In Canada, there has been a similar trend with increasing STEM in OST programs that connect students with professional scientists, such as "Let's Talk Science" (Ritz & Fan, 2014), or with undergraduate and graduate students, such as "WISE Kid-Netic Energy," an outreach initiative of the University of Manitoba's Faculty of Engineering (http://www.wisekidneticenergy.ca). Numerous other OST STEM programs in Canada are made possible through the sponsorship of companies such as the Imperial Oil Foundation (McKay, 2013), The Suncor Energy Foundation (Suncor Connections, 2015), Lockheed Martin Canada (2017), and the Hibernia Management and Development Company (Bruce-O'Connell, 2012).

Such after-school and out-of-school time programs fit somewhere between school science and museum science, drawing aspects from both (Schwartz & Noam, 2016). According to Schwartz and Noam (2016), museum science is more focused on personal growth, whereas classroom science is more focused on academics and students' education in, about, and through science. Museum science commonly occurs in informal learning environments where fun, play and learning can occur simultaneously (Gilbert, Rennie, & Stocklmayer, 2010). Thus, museum science centres create an environment where: a) visitors are in control of their own learning, and b) an aspect of satisfaction from entertainment occurs (Gilbert et al., 2010). After-school and OST programs strive to create an environment where informal and hands-on learning is supported (Schwartz & Noam, 2016). In the context of STEM, these programs focus on nurturing curiosity and engagement with certain topics or fields, including those fields in the acronym STEM (Noam & Shah, 2013). Schwartz and Noam (2016) argue that after-school science programs can reach a wider range of students and can attract more low-income families compared to museums and science centres. For my study, I focused on the research literature associated with after-school and OST programs related to academic institutions such as schools.

Research on after-school and out of school time science programs. The study of after-school and OST science programs is a relatively new field and, consequently, is lacking an all-inclusive and wide-ranging review of relevant literature (Schwartz & Noam, 2016). Most after-school and OST science programs are unique in their purpose and design and have been studied using a case study research design (Little, Wimer, & Weiss, 2008; Schwartz & Noam, 2016). These case studies have documented the following substantive and positive impacts that after-school and OST science programs are having: improvements in students' self-perception, social growth and behavior; enhancement of students' interest, engagement and confidence in science through development of their science knowledge and science skills and, thus, the fostering of favorable attitudes towards school science and science in society (Krishnamurthi et al., 2014; Schwartz & Noam, 2016). As one example, Krishnamurthi et al. (2014) make reference to a report that studied multiple after-school programs and found "students regularly participating in the programs improved their work habits; demonstrated higher levels of persistence; and saw reductions in reports of misconduct, such as skipping school" (p. 6). In addition, the authors describe a science club that connected youth in a Boys and Girls Club with scientists at Northwestern University. The youths' opportunity to interact with real scientists in laboratory activities led to the improvement of their scientific skills. They also found that "100 percent of Science Club youth came to see science as important for their future careers. This was 30 percentage points higher than control youth participating in the study" (p. 2).

After-school and OST science programs have also been identified as aiding in the improvement of socioeconomic and gender inequalities by closing achievement gaps in science and mathematics (Dietel & Huang, 2011; Schwartz & Noam, 2016). Krishnamurthi et al. (2014) report on the achievement gap between low and high-income families and assert that regular participation in after-school and OST programs aids in closing this gap by enhancing work habits, increasing school day attendance and improving overall academic performance. As well, there are many after-school and OST programs designed to encourage girls in pursuing school science and careers in science and STEM (Schwartz & Noam, 2016). Schwartz and Noam (2016) outline how girls can be held back from pursing science, especially mathematics and engineering, due to cultural and societal stereotypes, as well as a lack of opportunities, lack of role models and, in some cases, a lack of parental support. In after-school and OST programs, girls have opportunities to work with peers, form relationships with adults and work with female scientists (Krishnamurthi et al., 2014). As one example, a study of the after-school program Sisters4Science (S4S), created by a not-for profit science society based in Chicago, Illinois, reports on the program's success in improving the interests of women of colour in science (Lyon & Jafri, 2010). Lyon and Jafri (2010) discuss how many of the girls face multiple factors that deter them from studying science. This leads to a decrease in women pursing science related careers. The authors note: "recent reports suggest that women make up only 25 percent of the over 5 million scientists in the United States, and women of colour make up just 2 percent of that group" (p. 16). The girls participating in the S4S program showed an improvement in personal development, science abilities and interest in science. Moreover, the S4S program showed success in exposing students to the importance of STEM as a career.

Research on after-school and OST programs on students choosing STEM careers. The ASPIRES study in the United Kingdom (UK) (2014) reported on a lack of students, after the age of sixteen, choosing to study in areas supporting STEM-related careers, as well as these careers lacking middle class people, women and various ethnic groups. As in the US, the small number of students choosing to study STEM in the UK could have an adverse impact on the economy, with a gap in the development of important scientific skills that could lead to unfilled positions. This decline in interest in science, according to the ASPIRES Project (2014), is influenced by numerous factors such as family, stereotypes of scientists and misconceptions of how science is conducted. For instance, the report goes into detail explaining how families have a tremendous impact on students' interests in science. The nature of the impact depends on how knowledgeable the family is about science, and the value family members place on science. The authors of the ASPIRES Project (2014) state:

> Most young people and their parents have a narrow view of where science can lead. The widespread view – that science qualifications lead primarily to a job as either a scientist, science teacher or doctor – is contributing to many young people seeing post-16 science qualifications as "not relevant to me" (p. 3).

The ASPIRES (2014) study also found that the stereotypical images of intelligent, male scientists wearing white lab coats has had an impact on how students see themselves or, in some cases, do not see themselves as scientists. The authors claim that "gender issues are evident from a young age. Girls are less likely than boys to aspire to science careers, even though a higher percentage of girls than boys rate science as their favourite subject" (p. 3). These findings are consistent with the Afterschool Alliance (2011) paper that discusses a lack of women and ethnic minorities in the STEM workforce in the United States.

Clearly, there is a need for after-school and OST programs to aid in reducing stereotypes, under-represented groups in science, and improving attitudes towards STEM careers. According to Almarode, Dabney, Hazari, Miller-Friedmann, Sadler, Sonnet and Tai (2012), an important aspect when showing students how important science is for future careers is focusing on personal interest. In developing after-school and OST science programs the main goal should not be some form of academic achievement, but rather fostering a sense of inquisitiveness and gratification. Almarode et al. (2012) discuss a distinction between situational interest and individual interest, and even though the research shows a direct link between interest and student's choosing career paths in STEM, there is no consensus to what STEM activities best foster this interest. Moreover, the authors report that participating in after-school and OST science programs has a clear connection with students choosing STEM career paths. Similarly, the Afterschool Alliance (2011) review reports on several STEM programs that have fostered an improvement in students' attitudes towards the importance of STEM and choosing STEM careers. For example, the *Communication, Science, Technology, Engineering and Math (CSTEM)* program states: "94 percent of students reported that they want to continue in the CSTEM program…and 100 percent indicated that CSTEM provided them their first STEM enrichment experience" (Afterschool Alliance, 2010, p. 3). Further, the OST program known as *TechBridge*, which operates with girls from grades five to twelve, reported the following results: "95 percent believed engineering is a good career for women… 85 percent were more interested in working in technology, science or engineering because of role models and field trips… 82 percent could see themselves working in technology, science or engineering" (Afterschool Alliance, 2010, p. 5).

In addition to after-school and OST science programs aiding in the improvement of gender and ethnic inequalities in the field and improving student's attitudes towards choosing STEM career paths, these programs are also viewed as an opportunity to assist in closing achievement gaps in mathematics and science by improving test scores, skills, and motivation (Dietel & Huang, 2011; Noam & Schwart, 2016). As one example, Krishnamurthi et al. (2014) report on the math gap between low and high-income families and advocate that after-school and OST programs aid in closing this gap. Contradictory to this, Suter (2016) reports that fifteen-year-old students in twenty-eight countries who spent more time in after-school and OST science programs had lower scores on the Program of International Student Assessment (PISA), yet positive attitudes towards science. Suter (2016) calls for more studies to be conducted on the factors influencing student achievement scores on tests.

Features of successful after-school and out of school time programs. Since there has been success with students in after-school and OST science programs, there have also been case studies exploring what makes these programs successful for students. Unfortunately, there is no universal construct that definitively highlights what the best qualities are for designing and developing such programs (Schwartz & Noam, 2016). Much of the literature outlines common themes such as a highly-qualified staff, unique activities that are student centered, clear goals, a positive learning environment, and opportunities to cultivate peer-to-peer relationships (Afterschool Matters, 2010; Dietel & Huang, 2011; Schwartz & Noam, 2016). These features can be identified in the Maples Science Club GSBC project.

Maples Collegiate Science Club. Considering the previous discussion, the GSBC project has potential for making the Maples Collegiate Science Club a high-quality program. The activity is very hands-on and STEM-related, as the students must construct a payload that is launched by a weather balloon. This project is also very student-centred, focusing aspects of the activity on the group's interest. For example, the students with an interest in using Arduino software had to figure out how to program the software to record data from the payload; Many other students chose to join because of an interest in astronomy, physics, engineering and the chance to send a payload item into the upper atmosphere. Moreover, the staff involved with the club have science degrees and have taught science at the senior years level (Grades 9 -12) for many years. Further, the GSBC falls within STEM project-based learning. According to Duran, Höft, Lawson, Medjahed and Orady (2014), project-based learning can be a collaborative process embedded in social constructivism, and "within the context of social constructivism, design projects provide an environment for sustained inquiry and collective creativity" (p. 118).

The GSBC offers students the opportunity to work collaboratively to design and develop solutions to an authentic and unique problem. According to Herro and Quigley (2016), there is a connection between project-based learning and STEM. They argue that STEM project-based learning activities incorporating open-ended questions and relevant world issues aided students in seeing how STEM has real world applications. Chang, Chen, Lou, and Tseng (2011) maintain project-based learning can influence the building of good attitudes towards science for students. They report on studies by ChanLin (2008) and Karaman and Celik (2008) with results indicating that learners in project-based learning performed better in skill development, general ability and knowledge compilation than those who did not use project-based learning" (2013, p. 88). Duran et al. (2014) also discuss the connection between design-based learning, a student's personal interest, and choosing a STEM oriented career. Their study, which examined the impact of a collaborative inquiry and design-based afterschool program on urban high school students, led to two key discoveries. These are: 1) an increase in students' "understanding of what scientists, engineers, or mathematicians do and how they use IT [information technology] as they learn about and develop new concepts," and 2) students' affirmative change in attitude toward IT/STEM is "related to a positive attitude students bring to afterschool programs" (p. 130).

Looking deeper, Coleman and Mitchell (2014) report making a college course in first-year meteorology more hands-on, cooperative and student centered by introducing a high-altitude ballooning (HAB) project. In their study, they found their previous students had the expectation that the first-year meteorology course would be more hands-on, yet the course was mostly theoretical and mathematically based. Consequently, many of these students were turned off. When they implemented the HAB project, Coleman and Mitchell (2014) reported: "Direct observation has shown strong improvements in students' attitudes, including positive class evaluations and active student classroom engagement (i.e., strong class attendance and thoughtful participation)" (p. 30). Similarly, a HAB paper written by Beck-Winchatz and Hike (2015) concluded that, "HAB is an exciting way to engage students in a real-world science and engineering project" (p. 35).

Affective Attitudes towards Science

In this section, the literature associated with the measurement of student attitudes to science is reviewed. I begin with a working definition of affective attitude towards science and continue with descriptions of the methods for measuring student attitudes and the problems associated with quantitative questionnaires and scales. I end with a working definition of the Nature of Science (NOS), and the methods for determining students' ideas about science and scientists.

Definitions of attitude and attitude towards science. In a 1992 publication, social psychologist Alice Eagly defined attitude "as a tendency or state internal to the person…that biases or predisposed a person…toward favourable responses if the attitude is positive and toward unfavourable responses if the attitude is negative" (p. 694). One year later, she and her colleague Shelly Chaiken provided the following revision of this definition: "a psychological tendency that is expressed by evaluating a particular entity with some degree of favour or disfavour (Eagly & Chaiken, 1993, p. 1). They maintained that this definition incorporated the three essential features of attitudes, namely: tendency, entity [or attitude object], and evaluation" (Eagly & Chaiken, 2007, p. 583), where the attitude object can be things, people, places, events, or ideas, and "responses can be cognitive, affective or behavioural and overt or covert" (Eagly, 1992, p. 694). Liu (2010) claims that the attitudinal constructs that have been studied by science education researchers can be divided into those related to students and those related to teachers. Those of interest in this study are attitudes related to students, specifically student attitude towards school science, towards science teaching, towards labs, and towards science and technology.

In the science education research literature, attitudes towards science are focused on an individual's emotions and encompass a wide range of factors (Barmby, Jones, & Kind, 2007; Brickman & Lovelace, 2013; Francis & Greer, 1999; Osborne, Collins, & Simon, 2003). Osborne et al. (2003) define affective attitude towards science as "the feelings, beliefs and values held [by a person] about an object that may be the enterprise of science, school science, the impact of science on society or scientists themselves" (p. 1053). With this definition in mind, they suggest that attitude toward science consists of several interrelated constructs that include perception of the science teacher, anxiety toward science, the value of science, self-esteem related to science, motivation towards science, enjoyment of science, attitude of peers and friends toward science, attitude of parents toward science, the nature of the classroom environment, achievement in science, and fear of failure in science courses. In a publication focused on after-school science programs, Moreno, Newell, Tharp, Vogt and Zientek (2015) reiterated six of these aspects as having an impact on the students' attitudes to science: "a) student motivation, b) student self-concept, c) peer attitudes, d) classroom environment, e) perception of school science, and f) the difficulty of science." To these six, it is important to add gender and ethnicity as identified in Francis and Greer's 1999 study of secondary school science students.

The research on attitudes typically looks at the behaviour people take towards a certain item (Osborne et al., 2003). When discussing attitudes and behaviour, Osborne et al. (2003) contend that "attitude cannot be separated from its context and the underlying body of influences that determine its real significance" (p. 1055). As a consequence, the methods used to conduct research on attitudes generally focus on these influences. Potvin and Hasni (2014), however, warn that interest, motivation, and attitude (I/M/A) have different meanings and should not be conflated. They decide to exclude enjoyment in their review of 228 research articles focused on I/M/A, "because enjoyment 'can occur for many reasons, and interest is only one of them' (Krapp & Penzel, 2011, p. 30)" (p. 39).

Measuring students' attitudes towards science. There is not one instrument that is consistently used in measuring students' attitudes towards science (see Liu, 2010 for a list of survey instruments for measuring affective variables in science education), and there is no consensus on what attitudes towards science should be measured nor what the term "attitude" fully means (Barmby et al., 2007; Francis & Greer, 1999; Osborne et al., 2003). As a result, there have been a number of different instruments used in measuring students' attitudes towards science. For example, Chang et al. (2011) implemented a five-week science-technology-engineering and mathematics (STEM) study with thirty first-year engineering students that utilized a project-based learning activity. Their research goal was to measure students' attitudes towards STEM using a pre- and post-test STEM attitude questionnaire and a semi-structured interview at the end of the project. Using these instruments of measure, Chang et al. (2011) reported that “students had positive attitudes toward STEM, and they recognized the importance of STEM in the science and engineering disciplines” (p. 94). The interview questions focused on science indicated that the participants “preferred to learn science and obtain science related knowledge from practical experiments,” believed that “science is beneficial and can be generally applied to daily life,” and that “the possession of professional science knowledge is beneficial to one’s future career” (p. 94).

Francis and Greer (1999) developed a twenty item, three-point Likert scale questionnaire for 100 students in each of 24 secondary schools in Northern Ireland and analyzed the attitude to science data using SPSS software. These items ranged from “I do not have much interest in science” and “Scientific discoveries do more harm than good” to “I look forward very much to science lessons in school” and “Money spent on science is well worth spending” (p. 221). The analysis of variance statistics enabled Francis and Greer (1999) to conclude: “overall, males record a more positive attitude to science than females” and “younger pupils record a more positive attitude towards science than older pupils” (p. 223). Their findings were consistent with Osborne and colleagues’ (2003) review of attitudes towards science. In addition, they report a decline in attitudes towards science and interest in science once students entered secondary school. This effect occurred more in girls as they entered into higher grades of schooling.

In a 2016 paper, Hillman, List, Tilburg, and Zeeman argue for a science-related attitude instrument that would operationalize the affective domain independently of behavioural and cognitive domains. They then report on the development, field testing and validation of an instrument designed for use with students between the ages of eight and eighteen that was easily administered and simple to score. The instrument, titled “My Attitudes Toward Science (MATS),” has a grade 3 readability level and consists of forty items divided into what they consider to be the four subsets of student attitudes to science. These are "attitude towards the subject of science" (e.g., "Science is one of my favourite subjects" and "I often think, 'I cannot do this,' when science is being taught"), "desire to become a scientist" (e.g., "I would like a job as a scientist" and "I don't want a job as a scientist, because I have no interest in it"), "value of science to society" (e.g., "Our world is nicer to live in because of science and "Science in not useful to anyone but scientists"), and "perceptions of scientists" (e.g., Only thinking is important to scientists, not how they feel about something" and "If one scientist says an idea is true, all other scientists will believe it") (pp. 214-215). A student responds to each statement by selecting one answer "that shows how they feel" (i.e., disagree a lot, disagree a little, have not decided, agree a little, and agree a lot) (p. 215).

In reviewing the literature on students' attitude toward science and becoming aware of the instruments used to measure these attitudes, it became clear to me that the instruments used are rarely interviews or focus groups. Rather, they were most often questionnaires and surveys of some kind.

Issues with attitude to science questionnaires and scales. In light of the fact that there is no common instrument for measuring students' attitudes towards science, there has been criticism with what Potvin and Hasni (2014) identify as "the almost generalized use of questionnaires" in which the questions posed or statements made are limited to the declared perceptions of students, leaving out the personal experiences of the students (p. 111). This becomes even clearer when Osborne et al. (2003) write: "While they [attitude scales derived from such instruments] are useful in identifying the nature of the problem, they have been of little help in understanding it, which has led, more recently, to the growth of qualitative methodologies" (p. 1059). Further, Osborne and his colleagues discuss how very little research has been conducted so far using interviews as a qualitative method in measuring attitudes. Barmby et al. (2007) also examined the lack of qualitative methods in measuring students' attitudes towards science, and acknowledge that the fullness of the data gathered in interviews is better in understanding where these attitudes originate.

Call for studies on effect of after-school and out of school science programs on attitudes to science. There are clear benefits of after-school and OST programs for children, adolescents, and youth (Boys & Girls Clubs of Canada, 2011; Little, Wimer, &Weiss, 2008; Shernoff, 2010; Vandell, Reisner, & Pierce, 2007; Woodland, 2008). According to Schwartz and Noam (2016) there is a need, however, for more research on after-school and OST science programs and their impact on student's attitudes towards science. As previously discussed, there are various factors that can influence students' perceptions of science and whether they decide to pursue further education in science out of interest or as a career. The 2016 Maples Collegiate Science Club, with its focus on the GSBC project, is one example of an OST program with the capability to have a positive effect on students' attitudes towards science and technology and their understanding of the process of science.

Decline in Positive Student Attitudes Towards Science. A key aspect to student attitudes towards science is the perception of how school science is conducted. The ASPIRES study (2014) discusses how students' positive attitudes towards school science appear to diminish as they progress into high school. The authors report, "students seem to enjoy their lessons less over time, particularly as they move into Year 9, with progressively fewer students saying they learn interesting things, find science lessons exciting and look forward to science lessons" (ASPIRES, 2014, p. 17). Osborne et al. (2003) suggest this decline in positive student attitudes is being fuelled by the implementation of traditional curricula, where students are passive learners who are seldom challenged to think critically and to be creative. Within a traditional curriculum there are many teacher-structured laboratory activities. These traditional or “cookbook labs” lead students through a set of directions that only verify a pre-existing and known result (Cracolice & Monteyne, 2004; Lewandowski, Fineklstein, & Zwickl, 2013). Such laboratory activities, especially in senior science classes, can give students a false perception of what science is and how science is conducted. Lewandowski et al. (2013) explain how open or full inquiry-based labs give students a more accurate experience and understanding of what scientists do when conducting research. They write: “If we view labs as preparation for research, the most important criteria are that the activity accurately characterizes authentic research practices and students build on their prior knowledge – just as scientists do” (p. 5).

Many science laboratory activities at the senior years science level fail to use a student-centred approach “that begins with a student’s questions, followed by the student (or groups of students) designing and conducting an investigation or experiment and communicating results” (Martin-Hansen, 2002, p. 35). Moreover, Cracolice and Monteyne (2004) argue that traditional laboratory activities do not further student’s critical thinking skills or encourage them to think creatively. Engaging students in project-based learning activities, such as the GSBC, inspires critical thought, creativity, and collaboration and demands continuous problem solving. As discussed in Chapter 1, the students have to work together and agree on how to construct a payload that will hold all of their cameras and other scientific equipment, keeping everything under a weight restriction of 1500 g. It has been documented that other project-based learning activities have improved students’ attitudes towards science (Chang et al., 2011; Duran et al., 2014).

Research on the influence of Emotions on Learning

An aspect of learning, retaining and recalling information that can not be ignored is the influence of human emotions. It has been documented that emotions play a significant role in mental processing and has been associated with how we learn (Amin, Malaik, Tyng, & Saad, 2017; Campbell & Cleveland-Innes, 2012). Emotions can assist the brain on retaining and storing information. According to Campbell and Cleveland-Innes (2012) emotions cannot be viewed separate from the learning environment. Any educational materials should be developed taking into account how emotions could impact student engagement and learning (Amin et al., 2017). However, there is some uncertainty around exactly how emotions impact learning. For instance, Amin et al. (2017) discuss studies that have shown improved learning and academic success being associated with positive emotions, while negative emotions, such as being confused, can also have the same effect in enhancing learning due to an increase in student focus on the material being learned. Further, Campbell and Cleveland-Innes (2012) outline how negative emotions, such as stress, can assist in learning but also warn that too much stress can cause a negative outcome to learning. How emotions impact academic learning is a relativity new field of study that requires more research (Campbell & Cleveland-Innes, 2012). Moreover, much research to date has focused on students social-emotional growth and little research has been reported that focuses on students' emotional growth over various programs (Raffaelli & Villegas, 2018).

Raffaelli and Villegas define emotional learning as "the acquisition of skills to respond adaptively to demands, regulate emotions, achieve goals, maintain positive relationships, and handle challenging situations constructively" (2018, p. 1). They conducted a study that examined how students gain and develop emotional skills through participating in OST programs of leadership, arts and STEM. Their study examined three objectives: the emotional experiences, whether positive or negative, of youth in the OST programs; the emotional learning (how to comprehend and deal with emotions) youth gain from various sources including staff members, peers and self-reflection; and to examine how youth's emotional learning differed over the various programs.

It was found that positive emotions were most often experienced by students in all three types of OST programs with negative emotions experienced less often. In addition, positive emotions were associated with an increase in learning how to deal with emotions, and this was seen in all three types of OST programs. Students in the arts programs, however, reported more emotional learning from peers and staff members compared to those students in STEM and leadership programs. Negative emotions were best learned with the aid of peers and staff members rather than self-reflection techniques. Raffaelli and Villegas (2018) contend that negative emotions were more complex and that this was the reason youth drew more on their peers and staff for assistance rather than dealing with them on their own.

Clearly, emotions impact student learning. This area of research is recent and requires further research to fully understand how students' emotions are influenced by their learning environment (Campbell & Cleveland-Innes, 2012).

Nature of Science in School Science.

Since project-based learning is designed so that students are active participants in their learning, it also influences how students view the nature of science (Chang et al., 2011). Fifty-five years ago, Joseph Schwab (1962), biologist and curriculum theorist, argued for a school science that focused more on the processes of scientific inquiry and less on scientific knowledge (the products of science). This curricular stance was revived in the late 1980s when scientific literacy and public understanding of science, rather than career preparation, became the aim of K-12 science (American Association for the Advancement of Science, 1989; Matthews, 1994). Prominent science teacher educators and historian and philosophers of science began to write about the nature of science (NOS) for scientific literacy and the scope and nature of NOS in science education (Abd-El-Khalick, Bell, & Lederman, 1998; Clough, 1997; Driver, Leach, Millar, & Scott, 1996; Lederman, 1992; Matthews, 1994; McComas, 1998; Monk & Osborne, 1997; Osborne, 2002; Roberts, 2007; Stinner & Williams, 1998). Although there was not and continues not to be consensus on "what ideas about science should be taught in schools" (Allchen, 2013, p. 12), understanding of NOS as the epistemology of science (Lederman, 1992) by both students and teachers had become the central goal for achieving scientific literacy in curriculum documents (Hodson, 2008; Lederman, 2007; Matthews, 1994; National Research Council, 1996; Roth & Barton, 2004). Accordingly, "what science says about the world is only part of the story. A much bigger and more important part concerns the ways in which scientists generate and validate that knowledge, establish research priorities and use knowledge to address real world problems" (Hodson, 2009, p. 19). Similarly, Allchen (2013) stated:

> Sheer mastery of textbook concepts will not help [to achieve scientific literacy]. Rather, to inform real-life decisions, both personal and public, one needs knowledge *about how science works*. Knowledge of NOS may be as important–if not more important–than knowledge of content. (p. 3)

In 1996, Driver and her colleagues asked, "Why does understanding of the nature of science mater?" (p. 15). In the eight pages that followed this question, they provide justifications for a utilitarian argument, a democratic argument, a cultural argument, a moral argument, and a science learning argument. Lederman (2007) describes these arguments as "noble reasons for why science educators value NOS as an instructional outcome," but suggests they are intuitive, with little empirical support" (p. 832). He provides a list, not considered exhaustive, of what students should know and understand about NOS. This includes the following: "the crucial distinction between observation and inference; the distinction between scientific laws and theories; [the understanding that] even though scientific knowledge is, at least partially, based on and/or derived from observations of the natural world (i.e. empirical), it nevertheless involves human imagination and creativity; scientific knowledge is subjective and theory-laden; science as a human enterprise is practiced in the context of a larger culture, and its practitioners (scientists) are the product of that culture; and scientific knowledge is never absolute or certain (pp. 833-834).

There is no mention of science inquiry or the processes of science in what Lederman (2007) considers important. He is determined that this chapter in *Handbook of Research on Science Education* as well as the focus of NOS be the epistemological underpinnings of the activities of science, not the activities related to data collection, data analysis, and conclusions drawn from the data analysis.

NOS and project-based learning. Fostering understanding of NOS is where science activities embedded in project-based learning can have a positive influence on students' views of the nature of science, and, more pointedly, on students' perceptions of what scientists do and why (Chang et al, 2011). Project-based learning activities give students opportunities to engage in first-hand science and science and technology learning experiences that can be designed to more accurately represent how science is conducted within the scientific community (Herro & Quigley, 2016). In many classrooms, teachers too often engage students in confirmation labs that work towards confirming pre-known results. Such learning experiences do not often involve students in thinking critically, thinking creatively and drawing upon concepts and skills necessary in scientific work (Cracolice & Monteyne, 2004). As Lewandowski et al. (2013) contend: "Inquiry [in STEM] also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world" (p. 4). These few studies provide evidence that project-based learning has an impact on students' thinking process and can influence their views on the NOS.

NOS in Manitoba school science. The Manitoba government's 2011 Action Plan for Science Education in Manitoba states: "The development of increasingly scientifically literate individuals is one of the primary focuses of a 21st century approach to K-12 science education" (Manitoba Education and Training, 2011a). One of the five goals for science education addresses NOS. Students are to be prepared "to critically address science-related societal, economic, ethical and environmental issues" (Manitoba Education and Training, 2011b). One could also argue that aspects of NOS are implicit in an additional goal that enables students to use their scientific and technological knowledge to develop solutions to problems that will improve the quality of life for themselves and others. Such outcomes, however, greatly depend upon teachers adopting Hodson's (2003, 2014a) four basic learning goals for science education: learning science, learning about science, doing science, and engaging in socio-scientific issues. In the context of NOS, learning about science includes the following:

> Elements of the history, philosophy and sociology of science that will enable all students to leave school with robust knowledge about the nature of scientific inquiry and theory building, an understanding of the role and status of scientific knowledge, an ability to understand and use the language of science appropriately and effectively, the capacity to analyze, synthesize and evaluate knowledge claims, some insight into the sociocultural, economic and political factors that impact the priorities and conduct of science, a developing capacity to deal with the moral-ethical issues that attend some scientific and technological developments, and some experience of conducting scientific investigations for themselves and by themselves (Hodson, 2009, p. 18).

Embedded in such statements are what McComas and Olson (1998) refer to as NOS consensus items that they identified in eight international science education standards documents. Although problematic for some (Abd-El-Khalick, 2014; Allchen, 2013; Alters, 1997; Deng, Chai, Chen, & Tsai, 2011), considered by Hodson (2009) to be "educationally undesirable and inappropriate to the goal of critical scientific literacy" (p. 20), they are included here as they are statements that have made their way into magazines and journals for Grades 5-12 teachers (e.g., *Science Scope* and *The Science Teacher* published by National Science Teachers Association) and into the teaching of science in some Manitoba classrooms as a result of the specific learning outcomes (SLOs) in science curriculum documents. Examples of these SLOs include the Grade 7, Cluster 2, Outcome 04: "Explain what scientific theories are;" the Grade 7, Cluster 4, Outcome 12: "Describe evidence used to support the continental drift theory, and explain why this theory was not generally accepted by scientists;" the Grade 8, Cluster 1, Outcome 04: "Identify major events and technological innovations that have enabled scientists to increase our understanding of cell biology;" the Senior 1, Cluster 2, Outcome 02: "Investigate the historical progression of the atomic model," and the Senior 2, Cluster 4, Outcome 04: "Outline the historical development of the concepts of force and 'natural' motion"). The fourteen NOS consensus items are as follows:

> scientific knowledge while durable, has a tentative character; scientific knowledge relies heavily, but not entirely, on observation, experimental evidence, rational arguments, and scepticism; there is no one way to do science (there is no universal step-by-step scientific method); science is an attempt to explain natural phenomena; laws and theories serve different roles in science…theories do not become laws even with additional evidence; people for all cultures contribute to science; new knowledge must be reported clearly and openly; scientists require accurate record keeping, peer review and replicability;

observations are theory-laden; scientists are creative; the history of science reveals both an evolutionary and revolutionary character; science is part of social and cultural traditions; science and technology impact each other; and scientific ideas are affected by their social and historical milieu (McComas, Almazroa, & Clough, 1998, p. 513).

Researching NOS and student ideas about scientists and science. In published studies, it is becoming clear that if a few or many of NOS items listed by Lederman (2007) and McComas et al. (1998) are explicitly taught in school science, the sense students make of scientists and the nature of science is not often the meaning that science teachers intend. One reason is certainly the way scientists are portrayed in books, television programs, films, and internet websites. Another, as mentioned before, is the way students encounter science in school science lessons and the associated confirmation laboratory activities. A different explanation focuses on the science teacher (Adb-El-Khalick & Boujaoude, 1997; Clough, 2009; Lederman,1992, 1999; Pomeroy, 1993). In Lederman's 2007 review of teaching and learning of NOS and students' and teachers' conceptions of NOS, he attributes students' inadequate understanding of NOS to the ineffectiveness of teachers' interpretation and implementation/enactment of curricula within the classroom, teachers' inadequate views of NOS, and teacher's opinion that NOS instructional outcomes are not of the same status as "'traditional' subject matter outcomes" (p. 869). A fourth explanation, and perhaps the most disconcerting, is the realization that a student's authentic NOS understanding is difficult to elicit when using questionnaires and surveys, writing/drawing tasks, classroom and laboratory observations, and small group discussions (Hodson, 2009; Lederman, Wade, & Bell, 1998). Hodson (2009) and Lederman et al. (1998) attribute this to the philosophical stance of the researcher and, thus, the researcher's interpretation of student data, the language used to frame questions, the philosophical and/or socio-cultural/worldview bias of questionnaires and surveys, decontextualized questions, and the context in which the research occurs (e.g., in classrooms with group norms and peer group influences). Despite the concerns about the validity and reliability of student-generated NOS data (Coburn & Loving, 2002; Hodson, 2009; Leach, Millar, Ryder, & Séré, 2000; Newton & Newton, 1998), researchers have published numerous statements about students' views of scientists and the work that scientists do.

Methods of researching student views of NOS. Methods for determining students' views about scientists and science have largely been quantitative in nature (Deng et al., 2011). Hodson (2009) developed a list of the "best-known" NOS and processes of science questionnaires and cites research to suggest that the majority of these instruments created, before and during the 1960s, are "of severely limited value" given "significant [post-1970] work in the philosophy and sociology of science" (pp. 24-25). More recent questionnaire design that accounts for contemporary writing in philosophy and sociology, includes Views on Science-Technology-Society (VOSTS) (Aikenhead, & Ryan, 1992), Views of Nature of Science Questionnaire (VNOS-Form A) (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002) that is currently available in four additional versions (see Abd-El-Khalick, 2014 for "An Incomplete) List of Nature of Science Instruments (1954-2012)", and the Nature of Science Survey (Lederman et al., 2002). Further, according to Hogan (2000), much of students' explicit knowledge is a result of making inferences from the responses students provide to a researcher's prompts.

The VNOS, in all it's forms, is the questionnaire most frequently used in empirical research studies focused on ascertaining the NOS views of students, pre-service teachers, and in-service teachers (Abd-El-Khalick, 2014). It was developed in response to what Lederman and O'Malley (1990) considered to be a problem with paper and pencil NOS assessments and the discrepancies they noticed between their interpretations of written responses and interpretations that surfaced in interviews with participants following their completion of the questionnaire (Lederman, Wade, & Bell, 1998). Lederman and his colleagues state: “This unexpected finding (i.e., the purpose of the interviews was to help validate the paper and pencil survey that was used) was quite timely as it occurred when educational researchers were making a serious shift toward more qualitative, open-ended approaches to assessment of individuals’ understanding of any concept” (p. 610). These qualitative approaches would be interviews, focus groups, classroom and laboratory observations, and writing/drawing tasks.

Students’ views of the scientist and the Draw-A-Scientist Test. One writing /drawing task, developed in 1983 by Chambers, was the “Draw-A-Scientist Test” (DAST) that aimed to elicit primary/elementary school children’s thinking about scientists and the work scientists do. The Australian, American, and Canadian children in Chambers’ studies tended to draw older men with facial hair wearing lab coats and eye glasses. In fact, he states: “Only girls drew women scientists” (p. 261). The rooms in which the children showed the isolated scientist working generally included laboratory instruments and equipment, particularly beakers, flasks and test tubes in early years and microscopes, computers, electric wires, filing cabinets, and books and notebooks piled on desk tops in middle years. Chambers suggests that the image children had of scientists in 1983 differed little form Mead and Metraux’s 1957 image of the scientist as described to them by high school students in the United States:

> The scientist is a man who wears a white coat and works in a laboratory. He is elderly or middle aged and wears glasses … he may wear a beard … he is surrounded by equipment: test tubes, Bunsen burners, flasks, bottles, a jungle gym of blown glass tubes and weird machines with dials … he writes neatly in black notebooks … One day he may straighten up and shout: “I’ve found it! I’ve found it!” … Through his work people will have new and

> better products … he has kept dangerous secrets … his work may be dangerous … he is always reading a book (Chambers, 1983, p. 256).

This resonates with Hodson (2009) who cites numerous studies that present a more contemporary perception of scientists as:

> Exceptionally smart, hard-working … motivated by curiosity…and the desire to 'make the world a better place to live in' [if only for the purpose of] 'earning a good salary' or 'becoming famous' [and, yet, who are] seen as drab, uninteresting, introverted, unemotional, insensitive, socially inept, 'nerdy,' work-obsessed…sometimes highly secretive and occasionally sinister and dangerous, with few interests… [who] may neglect their family [as a result of working] long hours on problems that have little relevance to people or social issues. (p. 32)

Such stereotypical views are not likely to foster the interest of adolescents and teens in science and/or becoming a scientist. Fortunately there is research to suggest that interventions designed to explicitly address gender, ethnicity, and workplace can result in more realistic perceptions (Bodzin & Gehringerm 2001; Scherz & Oren, 2006), and that mistaken and exaggerated views can diminish with age when Kindergarten - Grade 12 students are taught about the nature of science and learn about scientific work (She, 1998; Smith, Maclin, Houghton, & Hennessey, 2000; Tucker-Raymond, Korzah, Pappas, Varelas, & Wentland 2007).

Calls for open-ended and qualitative assessments of NOS. In Lederman's 2007 review of NOS, he includes a synthesis of the "instruments purporting to assess NOS" (p. 867). He continues by mentioning a movement from "traditional convergent assessments" to ones that are more open-ended and attributes this to the difficulty many NOS researchers have realized when assessing "a construct as complex as NOS" with multiple choice and Likert-scales (p. 868). His hope is for researchers "to collect valid data [incorporating the voices of research participants] as opposed to large scale data sets" (p. 868).

More recently, Deng et al. (2011) reviewed 105 empirical studies that explored students' views of NOS (VNOS). They sorted these studies into three theoretical frameworks that they named "unidimensional (UD)," "multidimensional (MD)," and "argumentative (AR)" based upon the perception of VNOS represented by the author(s) of each study (p. 967). The UD framework identifies VNOS as decontextualized personal conceptions that occur in a continuum from empiricist to mixed to constructivist perspectives; the MD framework perceives VNOS as multiple, but independent dimensions that do not develop simultaneously and are part of one's schema or cognitive structures; and the AR framework sees VNOS as not being properties of individual students but as discursive achievements (e.g., can critically reason/argue about scientific claims/issues appropriately and can report VNOS in ways that are consistent with the NOS components reflected in the 1998 paper of McComas & Olson) (Deng et al., 2011, p. 967). Drawing from the research of the three theoretical frameworks, Deng et al. (2011) found very little correlation between demographics, gender and age in relation to students' VNOS, that students' VNOS is largely related to learning in science, and that inquiry, discussion, reflection, and/or argumentation activities have the most positive effect in changing students' views of the nature of science. Similar to Lederman's 2007 review, the authors suggest that an emphasis be placed on qualitative research methods and qualitative analyses such as conversation analysis and discourse analysis rather than discourse and content analysis categorized according to pre-existing groupings with the frequencies computed statistically. As previously mentioned, much of the research to investigate students' views of NOS has been with the use of semi-structured interviews, questionnaires, and surveys. The core limitation, with students' views of NOS, rests on classroom activities and how the teacher presents science.

Given the research literature, it is important that classroom-based learning experiences give students a valid perception of how scientists conduct science and why they work as they do. Buffler, Ibrahim, and Lubben (2007) report on a study that explored how students reacted to various approaches to the teaching of science, and they make the following comment: “If they perceive science as a collection of proven facts, they will focus on memorizing these ‘truths’ and will attempt to prove them through codified procedures provided by the scientific method” (p. 249). This will lead students to view science as a dispassionate pursuit, where no critical or creative process is taking place, only proving or disproving a hypothesis. Such teaching and learning results in students constructing an alternate and naïve perception of how science is carried out by the scientific community.

Summary of Chapter Two

The Maples 2016 GSBC falls under the description of an after-school and OST program (Shah & Noam, 2013; Schwartz & Noam, 2016). Afterschool and OST programs have been found to enhance personal growth and improve students' academic performance in school (Schwartz & Noam, 2016). When looking at OST programs with a STEM focus, these programs have been found to enhance students' interest in sciences, STEM careers, and attitudes towards science (Krishnamurthi et al, 2014; Schwartz & Noam, 2016). Further, STEM based-learning projects have been reported to positively impact students' views of the NOS, giving them the opportunity to apply classroom knowledge, think critically, creatively and obtain a better understanding of how scientists conduct science and why they do the things they do (Cracolice & Monteyne, 2004; Hodson, 2009; Lewandowski, 2013). There is a call for more opened qualitative research methods into understanding students' views of the NOS (Lederman, 2007). Much of the research has been quantitative in nature often leaving out the students' personal experiences (Lederman, 2007).

Chapter Three: Research Methodology

In this chapter, I summarize the background to the study and the purpose of the study. I then describe the theoretical framework and the research design. This is followed by ethical considerations, the procedure used to recruit participants and a description of the methods of data collection and data analysis. The chapter concludes with how validity, credibility and reliability of the study were ensured.

Background to the Study

As identified in the review of the literature, Out of School Time STEM programs have had positive impacts on improving students' attitudes towards school science, personal interest and confidence in science, understanding of science in society, and development of scientific skills and knowledge *of* and *about* science. The need for OST programs with a science focus was a consequence of employers seeking individuals with diverse backgrounds in science, technology, engineering and mathematics and recognizing the declining interest in science. Out of School Time programs have had positive effects on students' academic performance, behavior, and social development, and they aid in closing the educational gap between science and mathematics and disadvantaged groups of students, including visible minorities and girls. Furthermore, the literature reveals that students' having a positive view of the NOS can influence their science and science and technology interests, studies in all subject-specific aspects of STEM and future careers.

Identifying a Gap in the Literature.

In spite of such informative and promising results for OST science, science and technology, and STEM programs, there exists a gap in the research literature. Few published studies have been conducted on OST project-based programs with a STEM focus (Schwartz & Noam, 2016). Moreover, searches using ERIC: Education Database 1971-2016 retrieved zero results using the search items "global space balloon challenge" and six results using the search items "high altitude balloon." Of these six, two were academic papers where high altitude balloons (HABs) were used to either detect vapors and gaseous pollutants in the atmosphere or changes in ionizing cosmic radiation as a function of altitude. One of remaining four focused on aviation and incorporated box kites and model rockets rather than high altitude balloons. Three described science projects or experiments using HABs in undergraduate atmospheric science classes studying weather, as the culminating project in a senior year chemistry class studying experimental design, gas laws and air pollution, and in a class of Grade 5 students involved in a school-university partnership where the focus was designing payloads for a high-altitude balloon satellite (i.e., a stack of payloads attached to a HAB). In each of these three papers the data is anecdotal and focused on descriptions of the project or the learning experience provided.

A new search using the Academic Search Complete database 1959-2017 also retrieved zero results using the search items "global space balloon challenge" and 346 results using the search items "high altitude balloon." In an attempt to retrieve only texts and peer-reviewed journal articles related to HABs in science education, as opposed to science, the search terms "high altitude balloons in school" were used: Thirty-six publication were retrieved in this refined search, and 5 of these were focused on using HABs in K-12 education to: a) carry out experiments (e.g., the effect of altitude on weather balloon expansion rate; the effect of changes in radiation and temperature with altitude on yeast and plant seeds), or b) investigations (using what is known about air pressure and density varying with altitude to determine the assent rate of a high altitude balloon; maintaining a flight log). As with the ERIC search, there was no attempt in these papers to determine the attitudes to science or STEM of students engaged in the learning opportunities described, nor to identify the changes that may have occurred in their understanding of what scientists do and why. As such, there was potential for my study to contribute to the OST STEM research and research focused on OST problem-based learning, particularly with regards to attitude and conceptions of science and technology.

Research Methodology

The study was designed to explore what students learned as participants in the 2016 GSBC and how their participation in the 2016 GSBC project may have affected their attitudes towards science and perceptions of the way science is conducted. To this end, I elected to carry out a qualitative study. The majority of research studies designed to measure students' attitudes towards science or understanding of the nature of science (NOS) have traditionally used quantitative methods such as questionnaires and survey instruments with forced-choice items. With the exception of the Draw-A-Scientist Test and the addition of seven open-ended interview questions to the VNOS, very little of this research has used qualitative methods that incorporate the experiences of the participants (Bramby et al., 2007; Lederman, 2007; Osborne et. al., 2003). My qualitative study was composed of a small sample size, four of the ten eligible students, described in Chapter 4. This participation rate necessitated the gathering of rich descriptive data by means of one-on-one interviews, observations and video and photographic images. Collecting these types of data was to aid in the reliability and generalizability when interpreting results. From this data, I was able to inductively build concepts and theories about the participating students' learning, attitudes towards science and perceptions of how science is conducted by the community of scientists.

The 2016 Maples Collegiate GSBC project was unique with no predetermined procedure for constructing and launching the payload. The students had to make decisions about the construction and assembly from start to finish. When compared to practical work in science classes, this provided students with a series of unique problem-solving experiences. Qualitative inquiry seeks to understand a phenomenon from the point of view of the participants (Creswell, 2007). Using qualitative methods provided the opportunity to take an interpretative stance, where I was able to interpret each students' experience individually and analyse the complexity of views that emerge from the group's collective understandings. Moreover, the study focused on high school/senior years students. The majority of studies that I have read with a focus on attitudes to science and understanding of the nature of science have tended to focus on elementary, junior high school (middle years) and first-year university students. There are fewer published research studies focused on high school students involved in an out-of-school-time STEM-like project. As mentioned in the previous section, "Background to the Study," this research study was developed to address this specific gap in the literature.

The Research Questions

On the basis of the objectives of the research, and my attempt to link the objectives to the research problem, I formulated the following questions:

How did participating in the Global Space Balloon Challenge impact high school students' attitude towards science?

How did participating in the Global Space Balloon Challenge impact high school students' perceptions of how science is conducted?

Worldview of Qualitative Research

When attempting to explore attitude towards science and perceptions of science expressed by high school students who participated in the 2016 GSBC, I drew upon the paradigm or worldview of constructivism, specifically, social constructivism. According to Kim (2001), "social constructivism emphasizes the importance of culture and context in understanding what occurs in society and constructing knowledge based on this understanding" (What is Social Constructivism? Para. 1.). In other words, social constructivism is how individuals view the world and seek to understand it through their experiences (Creswell, 2007). As with the philosophical frameworks for positivism, post-positivism and critical theory, there are assumptions underpinning social constructivism that are related to the nature of reality (ontology), knowledge (epistemology), and learning (cognitive development). These assumptions are briefly described.

Reality. Social constructivists believe that reality is "socially and experientially based" and, thus, "constructed by and between people" (Bergman, de-Feijter, Frambach, Godefrooij, Slootweg, Stalmeijer, & van der Zwet, 2012, p. 545). As such, there is not one reality out there waiting to be observed and measured as a positivist orientation would have us believe (Merriam & Tisdell, 2016). Rather it exists as multiple truths constructed by members of a society that can "change, conflict, and/or become more crystallized" (Bergman, et al., 2012, p. 545). Given this supposition, every student from the 2016 GSBC interviewed was likely to have a slightly distinct perspective of the event.

Knowledge. Social constructivists believe that knowledge, like reality, is a human product that is socially and culturally constructed between interacting individuals who simultaneously interact with the environment in which they live (Kim, 2001). According to Creswell (2014):

> Individuals seek understanding of the world in which they live and work. They develop subjective meanings of their experiences. …Often these subjective meanings are negotiated socially and historically. In other words, they are not simply imprinted on individuals but are formed through interactions with others and through historical and cultural norms that operate in individuals' lives (p. 24-25).

The students from the 2016 GSBC have socially interacted with each other to build a payload filled with several types of equipment. Collaborating in this way the students were constructing knowledge from their interactions with one another and with the instruments and equipment.

Learning. Unlike the psychological constructivism of Jean Piaget where learning is "a process of personal, individual, intellectual construction arising from activity in the world" (Matthews, 1994, p. 138), the social constructivists, informed by the writing of Lev Vygotsky (1978), stress the importance of learning/cognitive development as a social process occurring with others (interpsychological) in language communities and then inside the individual (intrapsychological). I contend that the 2016 GSBC students were learning both inter-psychologically and intrapsychologically as they interacted and worked together.

Social constructivism was used to frame the study, to guide interpretations of data emerging from the study and to answer the research questions. The Maples Collegiate science students who participated in the 2016 GSBC constructed meaning through the use of hands-on/minds-on experiences and collaborative dialogue. Students actively engaged in a group setting where they shared ideas and thought through problems with guidance from their teachers. How students may have constructed and refined their conception of what scientists do and why, and their attitude toward science as a result of participating in the 2016 GSBC is difficult to directly assess. However, the subjective meanings of their interpretations of their experiences emerged from statements that were made during my interactions and dialogue with the participating students who agree to be interviewed.

It's important to mention the four characteristics that Merriam and Tisdell (2016) describe as "key to understanding the nature of qualitative research." These are: "the focus is on process, understanding, and meaning; the researcher is the primary instrument of data collection and analysis; the process is inductive; and the product is richly descriptive" (p. 15). As the primary instrument for data collection and analysis, I aimed to understand the conceptual and affective consequences of the 2016 GSBC for the participants. This was accomplished by attending to information from interviews, observations, photographs, videos, and documents and by working with this data to form general themes using what I had researched and scrutinized in the review of the literature on afterschool and OST programs, project-based learning, students' attitudes to science and STEM and students' views of NOS. I aimed to convey the meaning of the students' understanding of their GSBC experiences in richly descriptive words and images.

Using what I had learned from the literature review, I employed the theoretical framework of social constructivism and used this framework to determine my analytical framework. I drew from the reported conclusions of the cited case studies and paid attention to the similarities and differences between afterschool and OST science programs and the Maples Collegiate 2016 GSBC project. When considering students' attitudes towards science, knowledge of the various influencing factors was essential not only in formulating the open-ended interview questions but also in understanding students' interpretations of their experiences in school science, the Maples Collegiate Science Club and the 2016 GSBC. Finally, when drawing upon students' perceptions of how science is conducted, it was necessary to take into account published findings that pertain to students' views of the nature of science.

Research Design

A case study design was used in this study to gain an understanding of the experiences of the student participants in the GSBC. As Creswell (2014) describes:

> Case study research is a qualitative approach in which the investigator explores bounded system (a *case*) or multiple bounded systems (cases) over time, through detailed, in depth

> data collection involving *multiple sources of information* (e.g., observations, interviews, audio-visual material, and documents and reports), and reports a case *description* and case-based themes. (p. 97; emphasis in the original)

Creswell continues by explaining that "the unit of analysis in the case study might be multiple cases (a *multisite* study) or a single case (a *within-site* study)" (p. 97). Moreover, case studies are focused on "some real-life phenomenon that has some concrete manifestations" (Yin, 2014, p. 34) and are historical, biographical, or comparative (Merriam & Tisdell, 2016). In the study before you, the case is a within site, historical study of the 2016 Maples Collegiate GSBC. The unit of analysis is the experiences of the group of Maples Collegiate Science Club students who participated in the 2016 GSBC. This meets the definition of a qualitative case study as there is a limit to the number of students involved who could be interviewed and there was a finite time for observations. As such, it is a bounded system.

Once the case has been established, Yin (2014) suggests that it is important to define the boundaries of the case: to "distinguish data about the subject of your case study (the 'phenomenon') from data external to the case (the 'context')" (p. 34). I decided on the following criteria for inclusion: the thirteen Maples Collegiate Science Club students who participated in the 2016 GSBC launch day who were eighteen years in age or older. This excludes members of the Maples Collegiate Science Club who were not able to participate in the launching and retrieval of the weather balloon and its payload, as well as three of the thirteen students participating in the launch day who were under the age of eighteen, by the time of data collection, and the students from other schools participating in the 2016 Global Space Balloon Challenge who I only had the opportunity to meet on the day of the launch.

The case study is descriptive. Yin (2014) defines a descriptive case study as “a case study whose purpose it to describe a phenomenon (the ‘case’) in its real-world context” (p. 238). As stated above, this study was designed to understand the students’ interpretations of their experiences with the GSBC and the meaning they attribute to these experiences. To achieve these goals, I adhered to Creswell’s call for “in-depth data collection involving multiple sources of information” (2014, p. 97). Although more thoroughly described in the “Data Collection” section below, these sources include semi-structured interviews with students, photographs and video images, documents, and my own observations and experiences.

Researcher’s Position

I have a major in astrophysics and a minor in English from Saint Mary’s University in Halifax, Nova Scotia, as well as a secondary education degree from the University of Maine in Fort Kent. I have taught Physics 30S, Physics 40S, Astronomy 31G, Science 20F, Science 10F and Math 10F for approximately seven years at Maples Collegiate. During the 2016 GSBC I was teaching Astronomy 31G, Physics 40S, and Math 10F. As mentioned in Chapter 1, I was the head teacher for the 2015 GSBC and the 2016 GSBC projects within the Maples Science Club. All the potential participants in the study were former students in science courses I was responsible for teaching. My role in the 2016 GSBC could have influenced my interpretations of the data. To address this issue, I consulted with my thesis supervisor, and sought her perspectives on my analysis and interpretation of the data: the themes constructed, the key findings generated and their significance, and the conclusions drawn.

Ethical Considerations

The ethical standards described in the *Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans* (2014) were followed. These include the five criteria stated by Yin

(2014) for protecting participants: "gaining *informed consent,"* protecting "from any *harm*, including avoiding the use of any *deception*," protecting "*privacy and confidentiality*," taking precautions "to protect *especially vulnerable groups*," and "selecting participants *equitably*" (p. 78, emphasis in original). Recruitment and data collection methods adhered to strict ethical guidelines and begin after approval to conduct the study had been received from the Education/Nursing Research Ethics Board (ENREB) at the University of Manitoba (see "Research Ethics and Compliance Protocol Approval" in Appendix A). A copy of the "Letter of Invitation" sent to students meeting the criteria for participation, and a copy of the "Informed Consent Form for Participants" are included in Appendices C and D, respectively.

Recruitment of Participants

The procedure to recruit student participants involved purposeful sampling and, more specifically, criterion sampling (Creswell, 2007). Given the two criteria for defining the boundary of this case and, thus, inclusion, there was a small population of ten students from which to draw participants. Three of these ten students identified as female and seven identified as male. All were between the ages of seventeen and eighteen at the time of the GSBC launch and nine were in their graduating year.

Ten students were eligible to participate in the study, and all ten were sent letters of invitation. Forms for informed consent for the four students agreeing to participate in the study were reviewed and discussed on the date of, and immediately preceding the scheduled face-to-face interview. The interview began after the informed consent form has been signed and dated by the student and the researcher.

Data Collection

Data sources for the study included: (a) semi-structured interviews with each of the participating students; (b) curriculum documents from Manitoba Education and Youth, afterschool and out-of-school-time documents from Seven Oaks School Division, and Global Space Balloon Challenge documents from Rod Striemer, the Manitoba Association of Physics Teachers, and the GSBC website; (c) photographs and video taken during the 2016 GSBC launch at Morden Collegiate High School, and (d) my personal experiences/field observations with the 2015 and 2016 Global Space Balloon Challenges, the Maples Collegiate Science Club, the science program at Maples Collegiate.

Semi-structured interviews with students.

As mentioned, interviews with the participating students were held soon after receiving ethics approval for the study and positive responses to emailed letters inviting students to participate. Semi-structured interviews were used for the following three reasons. First, semi-structured interviews allow for focused, conversational, two-way communication. I wanted the participants to talk freely, but equally important for me as a new researcher was the opportunity to develop questions in advance of the interview that would serve as a guide in all interviews (see Appendix D for the semi-structured interview questions). Second, being semi-structured enables the researcher/interviewer to change the order of the questions, to alter the wording of a particular question, and to leave out a question that is, or questions that are redundant given the interviewee's comment or response to an earlier question or prompt. Third, this type of interview allows for conversations that may follow an unanticipated but potentially valuable theme.

The established set of interview questions was developed to elicit participants' experience of the GSBC and to determine if this experience had an effect on their attitude towards science/STEM and their understanding of how science is conducted. The interviews were scheduled for a time and place that was convenient for both the student participant and the researcher/interviewer. The average time for each interview was 30 minutes. Having received each participant's consent to audio record the interview, an Android tablet was used for audio recording. Transcriptions of the audio-recorded interviews were made by the researcher and an experienced transcriptionist who signed an oath of confidentiality (Appendix E).

Documents.

There are several curriculum documents that were used in making sense of the experiences of the participants in the study. These were framework or implementation documents developed by the Ministry of Education in Manitoba for four senior years (Grades 10-12) science courses. Each contains learning outcomes associated with the development of cognitive, scientific and technological skills and attitudes, the nature of science, the nature of technology and science knowledge (Manitoba Education, Citizenship and Youth, 2005 and 2006; Manitoba Education, Training and Youth, 2001; and Manitoba Education and Youth, 2003). As important to me and colleagues participating in the 2016 GSBC were the tutorials and forum on the Global Space Balloon Challenge website (https://www.balloonchallenge.org). The "Tutorial" is where one learns more about all aspects of the challenge, from the supply list to tracking and recovery of the payload. The "Forum" with its technical question and answer category is where one goes for help, troubleshooting, and shared experiences.

Photographs and videos.

In my possession are photographs of the 2016 GSBC students during the construction of the payload, as well as photographs and video taken on the day of the launch. Having attained permission for use from ENREB and the students participating in the study, I referred to these still and moving images during my analysis of the interview data.

Data analysis.

In designing the study, it was my intention to adhere to the process of data analysis described by Merriam and Tisdell (2016). This process involves simultaneous analysis of data as it is being collected. As such, at the end of the first interview and its prompt verbatim transcription, I read and reread the transcript and made notes in the margins that are my comments on what was said. Following this, I “wrote a memo” to myself that captured my “reflections, tentative themes, hunches, ideas, and things to pursue that are derived from this set of data” (p. 196). According to Merriam and Tisdell (2016), the information (“some pattern or theme,” p. 198) gleaned from this process would help me to know (a) what to ask in each subsequent interview and (b) the words and statements to look for when reading the transcription of subsequent interviews. They also suggest comparing my comments on the first set of data with my comments on the second and writing a second memo on what I am learning. This process was followed, as it allowed me to identify tentative categories for answering the research questions.

In addition to the “rudimentary [precoding] analysis” (Merriam & Tisdell, 2016, p. 200) described above, I coded the semi-structured interview data. Saldaña (2016) describes a code in qualitative data analysis as “a word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based or visual data” (What is a code? para. 1). Thus, codes are the thoughts that run through your mind as you read a transcript or document or set of field notes or view static or moving images. They are the result of an interpretive act, a judgment call, that translates and attributes “meaning to each individual datum for later purposes of pattern detection, categorization, assertion or proposition development, theory building, and other analytic processes" (Saldaña, 2016, What is a code? para. 3).

Coding.

Never having had the need or opportunity to code data, I used *NVivo 11*, a qualitative computer data analysis program to code the interview responses. My plan was to use an eclectic approach that makes use of attribute coding, structural coding, in vivo coding, and causation coding. Saldaña (2016) suggests that eclectic coding is "appropriate as an initial, exploratory technique with qualitative data … when combined first cycle coding methods [e.g., attribute, structural, in vivo, and causation] will serve the research study's questions and goals" (p. 213).

Attribute coding is a way of logging names, demographic characteristics, and role attributes of participants as well information about the setting, data collection format and time frame, and generic attributes of documents and media for analysis (Saldaña, 2016). Structural coding is used to label and index data. Saldaña (2016) describes this form of coding as a method of applying "a content-based or conceptual phrase representing a topic of inquiry to a segment of data that relates to a specific research question" (2016, p. 97). Such coding allows for quick access to data that is relevant to the analysis of a particular theme or larger data set. In vivo coding prioritizes and honours the voices of the participants by using participant-generated words or short phrases found in the interviews or video recordings. These codes "can provide a check on whether you [researcher] have grasped what is significant to the participant" (p. 107). Finally, the goal of causation coding is to understand the causal explanations of participants: "to uncover what people believe about events, [the mediating variable], and their causes [outcomes]" (p. 186). According to Saldaña (2016), causation coding is "appropriate if you are trying to evaluate the efficacy of a particular program" (p. 188), or in my case the impact of the 2016 GSBC on students' understanding of their experience and the effect of this experience on attitude towards science and perceptions of how science is conducted.

The subsequent forms of data analysis involved stepping back from the data and assigning units (codes) of data to tentative categories or themes "that seem to go together" (Merriam & Tisdell, 2016, p. 209) and reflect "the recurring regularities or patterns" in the study (206). This is where I applied the program *NVivo 11* to categorize the themes of the student interviews. These tentative categories were then tested against the data. According to Merriam and Tisdell (2016), categories, whether superordinate or subordinate, should be "responsive to the purpose of the research," "exhaustive," "mutually exclusive," "sensitive…to what is in the data," and "conceptually congruent" (p. 212). These categories are the findings of the study. Thus, the final step in the process of data analysis was my personal interpretation of the findings in light of information and theories reported in the research literature.

Credibility/Trustworthiness and Reliability/Dependability

Credibility in qualitative research is generally used to refer to the accuracy or authenticity of the results in portraying the views and meanings of participants' experiences. In the words of Merriam and Tisdell (2016), "the insights and conclusions…ring true to readers, practitioners, and other researchers" (p. 237). Reliability, on the other hand, generally refers the results of a study being replicated if the study is repeated. Given that there are numerous ways in which the data of a qualitative study can be interpreted, it is unlikely that the same findings would ever occur. Merriam and Tisdell (2016) argue that "this does not discredit the results of any particular [qualitative] study (2016, p. 250). They cite Lincoln and Guba's 1985 book, *Naturalistic Inquiry*, to suggest that reliability in qualitative inquiry be equivalent to the results being "dependable" and "consistent with the data collected" (p. 251). Creswell (2014) suggests that researchers incorporate what he labels “validity strategies” to increase their “ability to assess the accuracy of findings as well as convince readers of that accuracy” (p. 201). These eight strategies are triangulation, member checking, rich thick descriptions, clarification of researcher bias, presentation of negative or discrepant information, prolonged time in the field, peer debriefing, and use of an external auditor (pp. 201-202). I employed the first five strategies listed above, not the final three. I have identified “Impact of the 2016 Global Space Balloon Challenge on Student Attitudes towards Science and their Perceptions of how Science is Conducted” as an historical case study. That is, my study, begun in 2017, and the 2016 GSBC are not contemporaneous. A prolonged time in the field, when the world-wide launch occurs during a specified two-week period in April and on a specific date in southern Manitoba was not feasible. Moreover, I was never certain the Maples Collegiate GSBC would continue to receive funding following the 2016 launch. While I was interviewing, transcribing and coding during the summer of 2017 no peers were available for on-going debriefing. Finally, an external auditor may be important for research studies conducted by experienced researchers, but inappropriate for thesis research leading to a Master’s of Education degree where ability to design and carry out a study are components of the requirements of the degree.

Triangulation. I triangulated different data sources of information. This included the previously mentioned curriculum documents, the photographs and videos taken during the 2016 GSBC, semi-structured interviews with the student participants, and my own experiences as coordinator of the Maples Collegiate Science Club and GSBC.

Member checking. I sent each of the student participants in the study a copy of the transcription of their audio-recorded interview for revision. One transcript was returned to me as an email attachment with minor corrections (e.g., the removal of "umms"). The three remaining student participants sent emails to confirm that the transcriptions were accurate as written.

Rich thick descriptions. My descriptions may not be as "rich" and "thick" as Creswell describes owing to this being an historical case study that occurred in the spring of 2016. Even so, given the ways in which I analyzed the data, the descriptions are sufficiently detailed to "add to the validity of the findings" (Creswell, 2014, p. 201), as I have used detailed excerpts from the participant interviews to illustrate my findings and interpretations.

Clarifying researcher bias. I have included comments on interpretations that may have been shaped by "my gender, culture, history, and socioeconomic origin" (Creswell, 2014, p. 202). In addition, I have identified any preconceived notions of the GSBC having a positive effect on students that are a consequence of what I have read in the literature.

Negative case analysis. I was prepared to include negative or discrepant information and perspectives that contradicted an induced theme, as this evidence "adds credibility to an account… [by becoming] more realistic and more valid" (Creswell, 2014, p. 202). As a result of the small number of participating students, and the fact that all four were interested in STEM and successful in their senior year science courses, negative or discrepant information or contradictory perspectives were not identified in the data.

Summary of Chapter Three

In this chapter, I restated the purpose of the study, listed the research questions and described the theoretical framework of the study (social constructivism, attitude towards science and understanding of the nature of science), the research methodology (qualitative inquiry), and the research method (historical case study). This was followed by a positioning of myself with respect to the proposed study, ethical considerations, a description of the recruitment and sampling procedures, and the processes of data collection, data analysis, and data management. I ended by addressing how I ensured the credibility/trustworthiness and reliability/dependability of the study.

Chapter Four – Presentation of Data

From the list of ten students eligible to participate in the Global Space Balloon Challenge case study, four students responded positively to the invitation (Appendix C) and were interviewed. I begin this chapter with a brief description of each student. In an attempt to protect the identity of the four research participants, I refer to the students as Participant A, B, C, and D. Owing to the small number of female and male participants, I also use the pronoun “s/he” to disguise the participant’s gender in order to maintain confidentially. Following the descriptions, responses to each interview question are presented highlighting the similarities and/or differences in the answers given by each interviewee. It’s important to note that within the interview excerpts used in the chapter, many *ah, um, like, you know* and repeated phrases have been deleted. A series of three periods have been used to indicate phrases and sections of a passage not included in the quote.

Description of Participant A

The interview with Participant A took place in my classroom on September 29th, 2017 between the hours of 16:00 and 17:00. Participant A was a grade twelve student who I had taught in 40S Physics. At the time of the interview, s/he was again enrolled in science courses and managed to take all of the science courses offered at Maples Collegiate. S/He was actively involved in curricular and non-curricular activities offered by the school, and this included membership on the student council as well as the 2016 GSBC. Participant A was a dedicated, high achieving student with top grades who I noticed was always willing to take charge and learn new things. On occasion s/he would show off his/her intellect to peers, yet could on occasion be swayed by peers. Participant A is currently attending the University of Manitoba pursing a medical science degree.

Description of Participant B

Participant B was interviewed in my classroom on October 3rd, 2017 between the hours of 16:00 and 17:00. Participant B had participated in the 2015 launch as a student in my 40S Physics course. S/He was also a student in my Astronomy 31G class and a part of the Astronomy Club that evolved into the GSBC Club in 2016. S/He was a grade twelve student when the 2016 launch occurred. Participant B was a dedicated student who enrolled in many of the science courses offered at Maples Collegiate. As this student's teacher, I can attest to her/him having an independent personality and not being easily influenced by peers. Participant B is currently enrolled as an undergraduate student in the Faculty of Science at the University of Manitoba.

Description of Participant C

The thirty-minute interview with Participant C was conducted in a classroom at Maples Collegiate on October 11th, 2017 with a start time of 16:30. Participant C was in grade twelve during the 2016 GSBC club and launch. S/He was a very strong and dedicated student who took several science courses during her/his four years at Maples Collegiate, including my section of 30S Physics. Participant C was also involved in the arts programs offered at Maples, showing a well-rounded student with diverse interests, skills and abilities. S/He displayed a kind and polite temperament with peers, and as part of the 2016 GSBC was always willing to lend a hand where needed. Participant C is currently pursing an undergraduate degree in the Faculty of Engineering at the University of Manitoba.

Description of Participant D

Participant D was interviewed in my classroom on November 10th between 16:00 and -17:00. Participant D participated in the 2016 GSBC as well as the 2017 GSBC in their grade twelve year. S/He was interested in academic coursework and took many of the science courses offered at Maples Collegiate including 31G Astronomy and 40S Physics for which I was the teacher. My perception of Participant D is as a quite and thoughtful individual, who always had an inspirational quote and interesting insight into the world. During her/his senior year s/he attempted to start a club in order to develop further as a student leader. This leadership was demonstrated during the 2017 GSBC launch. As one of the most senior students with GSBC experience, s/he assisted in guiding the club and with the construction of the payload. Participant D is currently enrolled as an undergraduate student in the Faculty of Science at the University of Manitoba.

Based on my observations as a teacher, researcher, and supervisor of the 2016 GSBC, it is important to note that similar to Participant C, Participants A, B and D come from supportive families that encourage STEM involvement and who share a similar socio-economic standing. As such, the four Participants were a homogeneous group with no noteworthy differences between the responses of male and female Participants.

Responses to Interview Question 1: *How did the GSBC club first come to your attention?*

The four participants mentioned unique experiences hearing about the GSBC club. Participant A first heard about it through friends who had started joining the Club. Participant B recalled hearing about the 2016 GSBC from me during a meeting of the Astronomy Club that I supervised. Participant C knew of the 2015 GSBC as a Grade 11 student and heard about the 2016 GSBC and the GSBC Club through ads posted on the walls of the school and morning announcements. Participant D learned about the GSBC from me and participated in both the 2015 launch as a student enrolled in 40S Physics and the 2016 launch as a member of the GSBC Club.

Without being prompted, the four participants went beyond the surface of Question 1 and expressed various motivations to why they joined the club. Participant A had intended to participate in other school clubs when friends began joining the GSBC Club and was encouraged by them to join. S/He also recognized that the GSBC Club offered a more hands-on approach and described this as "one of the main reasons I wanted to join." Participant B also expressed wanting an experience that was hands-on and not traditional classroom work, such as labs and worksheets. S/He stated:

> I just wanted to get all the experience I could outside of the classroom, I suppose…other than homework. More…hands-on, like field day… Not just inside your classroom, but outside, hands-on applications of things we've learned and learning new things while doing the hands on. (Participant B)

Participant C expressed motivation to participate in the 2016 GSBC as steaming from personal interest that started with the influence of her/his father doing model airplanes while s/he was in elementary and junior high school. Participant C also described how the GSBC is a valuable way to introduce students to the STEM fields. The following interview excerpt illustrates this view:

> Well I've never done any space balloon launches or anything like that before, but I do kind of have a background in model aviation. Ever since I was a young kid, me and my dad built, fly, crash, rebuild model planes. That's kind of the main reason I'm going into engineering now. It's kind of those outside of school experiences, like the Global Space Balloon Challenge, that I think really let students realize what the STEM majors are all

> about. Because, in school, you have your typical classes, which I guess a lot of students don't see the practicality of. … It doesn't really have a lot of context, but when you introduce something like the Global Space Balloon Challenge, which is mostly practical and does require the application of some of the technical knowledge that you get through physics and math, I think that really gives students an insight into why you're learning what you're learning is valuable. (Participant C)

Participant D expressed an interest in joining the club once s/he had done more online research about the GSBC.

Responses to Interview Question 2: *Tell me about your experiences in the GSBC club. What things do you remember doing and learning in the GSBC club?*

To this question three out of four research participants responded similarly. Participants B, C, and D talked about the importance and challenge of effective communication in learning how to function as a team. This involved listening to each other, considering and evaluating each others' ideas and coming to consensus on the action to carry out. This shared perception was clearly expressed by Participant C:

> There's obviously in any team…a lot of different things that have to come into play. You have to have an overall idea of what the project is. Everybody has to be on the same page, and to get on the same page…requires a pretty high level of communication. I found that a big part of what the team was, was if you have an idea that's great, but if you are not able to effectively communicate that to the rest of the team, then it's not as valuable as it could be. I found that as you worked in a team and got to listen and learn from other people, it gave you a chance to consider other ideas and then, through the consideration of all ideas,

> come to the best conclusion of what the solution should be. Now as an engineering student I realize how important that still is. (Participant C)

Participant A expressed the enjoyment of meeting new people from different grade levels that s/he would never have met or talked to and teaching them things s/he had learned in class. In contrast to Participant A who didn't want to be bossy, Participant B expressed how s/he sometimes felt "a bit more assertive and bossy" towards GSBC Club members when it came to accomplishing tasks in a team setting. Further, Participant A talked about "learning quite a bit when it comes to problem solving," the relationship between being invested in the project and responsibility and how the project taught time management skills given the hard deadline for the launch. Participant B expressed how s/he "really enjoyed" the club and the opportunity to "hang out with like-minded people who like the same stuff as me." Participant D described how the GSBC taught her/him that in science it is okay to make mistakes if learning is being taken from those mistakes. The following interview excerpt illustrates this point:

> What I learned from the whole experience was that science doesn't happen in one room, from day to day classroom setting… What I also learned was we can perform a lot of science outside in an actual environment…and it's okay to make mistakes. As long as we learn from it and do something new in order to try and come up with ideas. It's something that we don't really see in labs or in [the] high school environment, or even in the university, for the most part, where we learn something. We get to - they - all the labs and

> everything are designed in a way to make sure that we are successful, we can get it. And in the actual Space Balloon Challenge what we learn as a team was that in science it's okay to make mistakes… (Participant D)

Participant D also discussed how s/he learned to be more of a leader during the 2017 GSBC launch by using the experiences of the pervious year's GSBC.

Responses to Interview Question 3: *Describe the days leading up to the launch. What were those days like?*

The four research participants described the days leading up to the launch as busy with final preparations, getting organized and communicating, either between group members or with me telling them about transportation to the launch site and when and where to meet. Participants A, B and C all expressed emotions of excitement and stress as things began to come together. Participant A talked about the stress in wanting everything to go smoothly, because s/he was in grade twelve and would more than likely not get another opportunity to do this project again. This following interview excerpt displays this emotion:

> Leading up to it was quite a stressful time. Because you needed to make sure that everything was going to be perfect, [that] nothing went wrong, because for us, the grade twelves that were involved, it's our last time to work on this. So, it was stressful for me. Other kids were just excited to have a day off from school…because they got to be outside to do something that they learned in class and apply it to the real world, which I guess physics doesn't really allow a lot of people to do. (Participant A)

Participant B's recollection were more specific as s/he focused on what was actually happening during the final club meetings:

> Most of what I remember is cutting up lots of that Styrofoam (laughs), and it being everywhere and then…lots of gluing and…just everybody's into something. Everyone is in different spots in the class…doing something to contribute to it, whether it be figuring out the cameras, figuring out where the camera goes, or, like, different compartments in the payload, or programming the Arduino and not messing up the knots of the parachute that connected the payload to the balloon itself. There was always something going [on]. …Nothing was ever boring, because there was always something happening (laughs). (Participant B)

All four participants commented on the members of the GSBC Science Club finally functioning as a team to accomplish one common goal. Participant D expressed how students had taken responsibility for the project and how having everyone on the same page reduced a lot of stress.

Responses to Interview Question 4: ***What challenges did you face in the club? – How did you over come them?***

When asked this question, Participants A, C and D talked about the challenges they faced in terms of the whole club collective. All three discussed aspects of how the group struggled with communication, getting everyone involved and coming to a final consensus on various decisions that had to be made. Participant A recalled how s/he had to listen to others and take their ideas into account as well as her/his own. Being a senior student on the project, s/he felt it was necessary to consider everyone's ideas so each GSBC Science Club member would feel they were involved and, thus, would have a more invested interest in the project. S/He said:

> That was the thing I had a challenge [with], because in school my main thing was, if there was a group project, I always just did it with somebody who was like, I knew they would just listen to me. I would do everything (laughs), and they would get the marks. I guess the club sort of taught me to make sure everybody gets involved. So that's like a big thing that I learned, to listen, to let everybody get a chance. (Participant A).

Participant C talked about how the GSBC Science Club members overcame these challenges of communication through getting to know each other over time and listening to other students' ideas. The following interview excerpt from Participant C shows this idea:

> Well a challenge I would say, again kind of going back to the whole communication thing. I found that there were times when we all had our own ideas of what can happen. For example, where the cameras were going to be mounted. I remember there was confusion over where they were going to go, how they were going to be mounted. I found one of the challenges, the biggest, would be coming to a consensus to what the final decision would be. Because everybody's got their own ideas of what it should be, and I found, coming to a consensus of what the final decision was, to be a good challenge. … At the beginning everybody was really excited, really anxious, so it was hard to kind of settle down and

> listen. But I found as time went on, and we had time to really wait things out … and I found that, you know, that everybody just kind of settling down and listening really allowed everybody to put forth their ideas. (Participant C)

Participant D brought forth an interesting perspective having gone through two GSBC launches (as did Participant B). S/he expresses the same challenges Participants A and C mentioned, but discusses how on the second launch the group dynamic was very different in that they had to re-establish as a team with essentially new members. Recall from Chapter 1 that I had originally conducted the GSBC project with all of the students my senior physics course, who graduated at the end of the year leaving no experienced students for the 2016 GSBC Club. Participant D discusses how s/he took a leadership role within the club, taking all students' ideas into account and teaching them what worked and did not work in the design, construction and launch of the 2015 payload. This act of communication on Participant D's part helped to get the students working as a team.

Participant B, on the other hand, reported not having any personal challenges to overcome within the 2016 GSBC Club, but s/he talked about the ongoing challenge of arranging times when students were to meet after school to work on the project "because everyone had their different schedules" as well as the challenges encountered during the launch of the payload in 2015.

Responses to Interview Question 5: ***Describe the day of the launch. What do you remember?***

When reading the responses to this question and Interview Question 6, it's important to remember that the 2016 GSBC took place on the grounds of Morden Collegiate (approximately

140 kilometers south and west of Maples Collegiate), and that two attempts had to be made to launch the weather balloon with its payload. In the first attempt the balloon and payload ascended for a few meters then quickly descended. It was determined that there was insufficient helium in the weather balloon to lift the payload. The second launch was successful.

All four research participants expressed emotions of excitement, anxiety and stress during the day of the launch. According to Participant D, "launching was, is usually, actually is the most stressful." S/he remembered that on the day of the launch they had to remove parts from the payload because it seemed too heavy and described this redesign as "really stressful".

Participant B's response to Question 5 captures her/his perception of the day in the following account:

> Sugar fueled, then caffeine fueled (laughs). Getting up early, arriving here [Maples Collegiate], making sure to document everything, so we don't forget what we did and keep the good memories. Being pretty cautious around the set-up station [at the site] and yelling at everybody with shoes on. Making sure that everything is going smoothly. I guess you could say its kind of like rocket surgery (laughs), cause, like one small move [that's] wrong, and it's finished. Like in 2015 when the balloon actually flew away (laughs). (Participant B)

Participant C, in contrast, was joyous in his/her response:

> I remember on the day we had set up the payload and inflated the balloon and everything was going according to plan, except like in any engineering task there's always the possibility of a slight failure, which there was. I remember it didn't quite launch the first

time. … But, nevertheless, we did deal with that, and we were able to launch, get it up there, get our [video] footage, get our data and locate it and get it. So that was definitely a once in a lifetime experience. To know what you fabricated (laughs) went up to space, came down, and was retrieved and actually provided you with something. … We got a lot of data. We got a lot of camera footage. And just knowing that your group was responsible for that.

Participant A talked about the experiences collaborating with other high schools on the day of the launch. For the first time the Maples team had the opportunity to see how other school teams constructed their payload and compare notes. S/he describes this opportunity as follows:

> We were all very curious about what other kids had tried out, and a lot of them were pretty cool. We never put a lot of design into ours, like made it fancy. Like say we made it into a sphere; something that I guess somebody tried. We just wanted a simple box that was purely functional [and] got the data we needed. (Participant A).

Responses to Interview Question 6: ***What challenges did you face during the launch day? How did you over come them?***

The four research participants discussed challenges when describing the day of the launch in Question 5. As previously mentioned, Participant B had been involved in two launches (i.e., the 2015 and 2016 GSBC launch days). S/He describes how the first launch was a great opportunity to be involved and learn, and how this assisted in preparing for the 2016 GSBC. S/He describes the challenge of the stress and anxiety felt during the launch and how this was overcome through team work. The following interview excerpt demonstrates this point:

> The troubleshooting part of the relaunch was definitely nerve wracking, especially when I was one of the hands holding onto the neck of the balloon thinking "what if I'm the person who lets this go?" I wouldn't be able to live with myself if that happened. Just mostly the fear that I might be the one to cause a catastrophe (laughs). Well there's other people around me making sure we are all working as a team to make sure that wouldn't happen. So even if one of us did screw up, it's not necessarily "you're the weakest link so the whole thing is going to go under". So as long as everyone else is there putting in their effort everything should run smoothly, theoretically at least (laughs) (Participant B)

Participant B also mentioned every team on the field being "nervous about one kid flying a drone." They realized, given the light mass of a drone, if a gust of wind were to direct it toward a balloon and make contact with the balloon, it would "basically flush five-hundred dollars down the drain."

Participant A talks about overcoming the challenges of possibly forgetting items needed for the launch and double checking everything before leaving the school to travel to the launch site in Morden. She said, "I was just making sure that everything got into the car… We had a lot of things and [when] you always have a lot of things you always end up forgetting the most important thing. So, I was worried. What if we forget the entire box we are trying to launch into space, and we just have the balloon and the tank? (laughs)."

Each participant brought up the memory of their payload launching, traveling up into the air and then suddenly crashing back down due to lack of helium and a payload that was a little too heavy. Participant D described the group as not functioning well as a team and being scattered, and gave this as an explanation for why the payload initially crashed. S/He shared the following:

> On the first launch everyone was doing their own thing. I mean that was one of the biggest things that we were able to overcome the second time. But on the first very launch, we were doing our own thing, we didn't really have teams, we didn't have all the work divided. It was pretty much everyone did what they, what they wanted to do. … I remember while we were working on the thread for the parachute for the actual balloon, one of the [students] put a muffin (laughs) in our payload. Since no one was paying attention…we had no idea. When we tried to launch the balloon, everyone was really excited that we were going to get it the first time and (laughs). Unfortunately, ours didn't. Then we opened the payload, and we found the muffin was in there (laughs). Another thing that happened that day was our helium tank was leaking […] (Participant D)

According to Participants A and C it wasn't only the muffin that caused the first launch to fail. In the final minutes before the launch, members of Maples team started loading food items and sentimental things to the payload that they wanted to send into space. Participant A suggested that "the mass that we wanted to send up didn't correlate with the gasses in the balloon. …We didn't measure the weight in class and then make sure…how much volume [of helium] we needed in the balloon." Participant C described removing everything so that they could successfully launch as "probably the main challenge on that day." Even so, s/he reflected on the premature end to the first launch by describing the event as a "learning experience in itself, because it went to show that no matter how extensive your planning and your preparation is, things can always go unplanned. But, nevertheless, we did deal with that. … That was definitely a once in a life time experience."

Responses to Interview Question 7: *Can you tell me about the benefits of joining the GSBC Club?*

The research participants responded to this question by expressing how the GSBC had provided them with the opportunity to apply what they learned in their high school science classes in a "fun" and "hands-on" way. Participants B, C, and D talked about how the GSBC is not something you can do or learn by simply sitting in a classroom. Participant B recalled the experience as pushing her/him to grow personally and to appreciate an out-of-school time experience that wasn't assessed. The following excerpt illustrates this point:

> […] mostly the hands-on experience, and that I'm actually a part of something extracurricular not just going to classes. … It's just nice to have something outside the classroom that's not necessarily a mark on paper, but I guess on your life… I was a part of this project and I got to learn all these things that I wouldn't necessarily learn sitting in a desk and chair and taking notes, you know … I guess out of my shell too (laughs). (Participant B)

Participant A also discussed how the experience is unique, and how it gives students a good introduction into what science is like. S/He said:

> A lot of kids won't get the chance to do this in their high schools, which is quite sad because it's the coolest experience we could have as young kids who are just entering the science field not even knowing that they like science. Because I remember we had a grade nine student who actually loved physics afterwards. … It helps a lot of kids consider physics as a career, because it's sort of that dark area of science, …When kids say they don't like physics… I'm like "what's not to like about it?" This is literally explaining how the world works in math. (Participant A)

Participant A continues by discussing how the GSBC pushed the 2016 team to take into account multiple variables that were not found in their classroom labs. The following interview excerpt illustrates this point:

> This [project] got to look into an area, which we sort of ignore in physics, which is different variables that we never considered. Like this year, you had to learn about jet streams in the air that can pull an entire balloon away from what we predict. That's sort of what I'm looking into…applying different things to like see, okay, if I add air friction, how can I calculate this? How much air can the balloon take and travel which direction and see it all. It was [applying] cool variables that we never got to experience in labs. In labs we never do something like this. (Participant A)

Participant C expands on the application of science knowledge and discusses how students can lose the importance of what they are learning in a classroom. The GSBC gives meaning to learned knowledge by getting students to apply it to a real-world application. S/He stated:

> It gives students an opportunity to get outside of the classroom, but still engage in an academic environment. In the classroom things get more and more complicated. They can start to lose importance, for example, when you're doing a chemistry calculation that might seem meaningless, not very valuable. But when you experience something like the Global Space Challenge, in order to understand how it works you have to apply that knowledge. That's when students really understand why they're learning what they're learning. And I think in that sense it's really a valuable experience for students and everybody else who might participate. … It gives them the opportunity to realise that science, math that they're learning in school does have significance and an importance. (Participant C)

Participant D also described how getting outside of the classroom forced the students to not only socialize more but showed them that nothing is guaranteed to work out well. This excerpt for the interview illustrates this point:

> We get to learn something that we cannot learn in a classroom, where everything [that] is done, is given so get we everything perfect.… Once you're in the classroom setting, you are given a certain assigned task and that usually is made out to work out in the end. It all depends on if you put in some effort. But then when we went outside the classroom setting, we had to do everything by ourselves, take responsibility and even though we had a really good understanding, it doesn't mean that it was going to work out in the end. (Participant D)

Participant A talked about the emotions associated with the launch day, and how s/he came to realize that the more emotionally involved you are in something the more you will remember what you learned. S/He also mentioned thinking back to the GSBC 2016 experience when answering final exam questions in an undergraduate level physics course. When prompted about the benefits of the GSBC Science Club, Participant A described how connecting with other students in various grades was a positive experience. S/He also said:

> It pushed me more into the physics area, because there's more to it than we can see. And that's sort of why I'm doing medical physics research [with a professor]. … This is a weird field that I never even thought about, and its sort of opened my mind to, like, okay, there's stuff going on, I should attempt it and see what I can do with it. … I never would have contacted the prof if I'd never, like took physics in high school. (Participant A)

Participant A also shared his/her experiences of the GSBC with a few of his/her professors:

> "They were so interested this. They actually brought their friends together and listened to what I was saying. … They were actually considering doing this as a side project during the summer with their students. … I think they might even consider it, because they are like this might be a good bonding project that we would do with our new students that come from other provinces."

Responses to Interview Question 8: ***Have you done anything like this project before hand?***

Whether in-school or out-of-school, Participants A, B and D had not previously experienced a STEM-based learning project such as the GSBC. When asked the question, Participant A responded, "No. … Nothing like this ever. Not even in university does anything [occur] that's this interesting." Participant D, in a similar fashion, said, "No. It is really a new experience. I never knew you would actually, in high school, build a payload and actually launch into space, not space but higher altitude, and get some data, do research if you want, [and] interpret those results. In responding, Participant B focused on the practical/hands-on components of the GSBC. S/He responded:

> "In physics, in my experience, I haven't really done anything of that magnitude for hands-on. Mostly your typical, like, okay, here's your experiment, you're going to figure out force, prove this, like, formula that's true. Just that typical stuff. Or, today we're making esters in chemistry [said with sarcasm]. Woo hoo! Nothing, like, crazy, okay we're gonna spend lots of time after school, we're gonna go out in the middle of nowhere and to this and it's gonna be awesome and crazy." (Participant B)

Participant C, by contrast, had a background in fabricating, flying, and re-building model airplanes with her/his father. As was mentioned in her/his response to Interview Question 1, these experiences with aviation were the reason s/he decided to purse an undergraduate degree in engineering.

Participant C talked about how the GSBC is great for student majoring in sciences, mathematics and engineering studies, as it not only gives a real sense of where they can apply knowledge they learned in the classroom directly, but also gives them "the opportunity to learn hands-on skills, group skills, and some things [that] in the classroom you don't get." S/he describes such learning experiences as complimenting "the technical side of school, which some people only have." In fact, it was discussions about the GSBC with other students, both in high school and university, who "never had anything like that" and wished they had, that helped Participant C to "realize how valuable this [GSBC experience] is."

Having never experienced a project like the GSBC, Participant B talked about how the GSBC allowed one to learn things that wouldn't necessarily be learned sitting at a desk taking notes. One important aspect s/he mentioned was the complex set of variables, which are not often present in classroom labs, that had to be critically think through within the GSBC. This view is illustrated in the following interview excerpt:

> When you're in a classroom, you're just siting there. You could solve a problem on paper and it's ideal conditions, like, there's no other weird variables that are given. … You're boxed in and things are more rigid. Well, when you're out there, it's like you have a general plan, but you have to improvise more times. When you're writing a test you don't improvise. You either have the answer or you don't. Well, out there, there it's like, it could be A or B or it could be C. … It's more fluid, more or less like a weird type of flow to the work you do. (Participant B)

Responses to Interview Question 9: ***How have these experiences impacted your views on how science is conducted?***

For this question the four participants again stated that the GSBC is not something you could do in a classroom, nor was it something they had ever experienced in a classroom laboratory setting. Participants B and D commented on how experiments never go as planned, and that there will always be things you can't control. Participant B talked about how s/he initially pictured science as being conducted in a clean setting with people in lab coats, looking sombre, and writing out long formulas on whiteboards. The GSBC was not like the stereotypes they had in mind. It was more fluid, with more room to experiment, reflect and then go back and try new ideas. An excerpt from Participant B reveals this point:

> There's no definitive formula that you have to follow in order to make this thing take off the ground. Well there is, but, like, not like precisely this! … There is more wiggle room I guess for error. … It's not necessarily discovering something new … conducting science and stuff, and I guess experiments, it's not supposed to go all to plan, to go smoothly. There is always going to be set backs, but then you have to reflect on that and say okay, here's my result, here's what I did, what did I do to get here and why is this different from the result that I wanted. (Participant B)

Participant D commented on the education system and how it constructed for students to succeed, especially during most classroom labs. In the excerpt below, s/he talks about how this is not the way science is conducted in the work place.

> As I said earlier, not everything will work as perfectly and [that's] also a good thing when it comes to learning, because throughout our high school and even in our university education we are taught that it is really bad to make mistakes. We are judged based on the mistakes we make. When you're out there in [the] actual job you will be doing, … especially as a scientist or researcher, it's really important to know that it's okay, because although you are able to hypothesize, not everything you can actually do an experiment on. You must be able to work around, come with different ideas, not just one, [but] come with separate ideas, so if one doesn't work maybe the other one will work. And, perseverance. I think that is one of the biggest things when it comes down to anything. (Participant D)

Participant D continues her response to the question by linking this perception of mistakes to students only caring about grades and not what they are actually learning. She said:

> The thing is now…as we go [forward] more and more students are interested in getting that grade other that the actual learning behind it. It's the reason why we cheat. I think that's something Neil deGrasse Tyson said, that the reason why students cheat is because they don't respect learning. And that is what we are being taught, to care more about getting that grade than to be actually able to learn. (Participant D)

Participant C discussed how the GSBC shows students all the sides of science, thus, yielding a more complete view of how knowledge learned in the classroom can be applied to various phenomena, events and organisms:

> It reveals the different faces of science. […] There's the technical side, the practical side, the communication side. And it's kind of the marriage of all of those things that make science what it is. It's not just technical knowledge, because technical knowledge is good and great, but unless you can apply it, it can be kind of useless. I think it's opportunities like this that really sheds light on that. Like, you know, how important it is to the technical knowledge, but how probably even more important it is to be able to apply and know it, not just memorize it. It gives students the opportunity to really give context to what they're learning. (Participant C)

Participant A interpreted this question slightly differently than the other three participants in the study. I had changed the question to *How was your experiences with science in high school compared to this launch?* The answer provided was included in her/his response to Question 7.

Chapter Five – Findings and Discussion

In this chapter, the methods described in Chapter 3 are used to analyse and interpret the raw data presented in the previous Chapter 4. I begin by recounting the manner in which interview data were coded and the process from which themes emerged. This is followed with a tabulation of the identified themes associated with each research question. I conclude with findings that correspond with each major theme.

Data was initially analyzed by reading through each participant's transcribed interview, making notes in the margins, and high-lightening meaningful sentences and paragraphs. Blue sticky notes were used to identify responses that fell within my first research question: How does the GSBC impact high school student's attitudes towards science? Yellow sticky notes were used to identify the responses that fell within my second research question: How does the GBSC impact high school student's perception of how science is conducted? Following this basic sorting, the transcriptions were uploaded to the qualitative data analysis software program *NVivo11*, and I revisited the sections of the transcripts that had been sorted using the two research questions. As I read, I pulled out phrases from the responses of the participants and gave these excerpts labels that were meant to summarize the participant's views and/or feelings. While working through the four transcripts, these labels began to show groupings. Thus, I began sorting the labels according to these larger themes. Figure 3 is a screen shot of the themes from *NVivo11*.

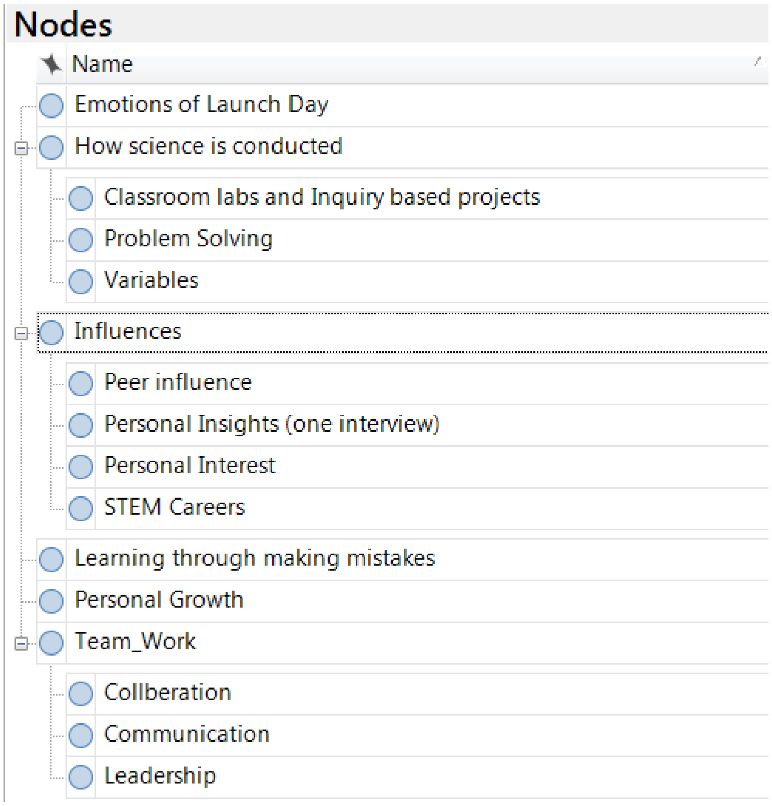

Figure 3. Groupings of themes created in the *NVivo 11* program from the participants interviews.

One particular theme emerged that was unexpected, specifically the theme of participants being emotionally involved in their learning. Initially, I thought it strayed from the research questions, but, after a deeper examination I realized that it brought a new perspective that I had not considered and related to the impact of the GSBC on high school student’s attitudes towards science. A list of the identified themes is presented in Table 1.

Table 1

Emergent themes from the transcribed interviews

Attitudes towards science	Perceptions of how science is conducted
Family, peers, and personal interest in the natural sciences	Trial and error as part of the process of science
Emotional involvement in what is being learned	Problem solving when suddenly faced with more than one issue
Stereotypes of physics and STEM careers	Importance of communication within the GBSC team
Perceiving school science subjects as content and content specific with limited, if any, understanding of NOS	Application of integrated science content knowledge in STEM projects
Personal growth within OST STEM-based learning projects	

Prior to discussing each theme identified in Table 1, it's important to point out the overlap that exists between the themes placed in each specific column. By overlap I mean that the themes are not clearly separated in nature or distinct, as the following two examples illustrate. The participants' experiences of problem solving within the GSBC when simultaneously faced with several critical issues impacted their perceptions of the relevance of high school science in the real world. Frequently, and with little forewarning, the participants had to apply what they learned in the classroom to the GSBC. Moreover, students' teamwork experiences and communication within the GSBC impacted their personal growth.

I begin my analysis by focusing on each emergent theme under the Table 1 heading "Attitude towards science" and then address each emergent theme under the heading "Perception of how science is conducted."

The Impact of the GSBC on Participants' Attitudes Towards Science.

Family, peers, and personal interest in the natural sciences. A common thread was personal interest. They joined because they had a predilection for science (see pages 61-63 for descriptions of the participants), or because they wanted a more hands-on experience that would be different from what they were experiencing at school and in the classroom. Participant A described the GSBC as offering a hands-on approach and said that this was "one of the main reasons I wanted to join." Similarly, Participant B "wanted to get all the experience s/he could outside of the classroom" as well as "hands-on application of things we've learned and learning new things while doing the hands-on." Participant C, with a family member who influenced her/his personal interest in engineering through model aviation, joined the GSBC Science Club because s/he had "never done any space balloon launches or anything like that before." It was also this research participant who attributed the GSBS to fuelling his/her interest in STEM careers and believed that "outside of school experiences, like the Global Space Balloon Challenge…really let students realize what the STEM majors are all about."

In addition, the participants reported on the influence of peers and family, as well as personal interest in driving them to join the GSBC Science Club and pursue STEM studies at university. Drawing from my observations as team leader of the GSBC, I witnessed these four students having a personal interest in science and often conversing about their science subjects and the science subjects and programs they were planning to take at the post secondary level.

According to the literature reviewed in Chapter 2, there are several factors that can impact students' attitudes towards science. These include family, peer and personal thoughts as well as perspectives about science (Moreno et al., 2015). Following graduation from high school, the four participants chose to pursue science or engineering at the post-secondary level. Given their responses to the first interview question it's clear that the influence of family and peers was a positive one for the majority of participants. Moreover, the decision to join the GSBC in seeking a more hands-on experience brought relevance to the classroom science to which they were exposed. One could argue that these students were searching for a richer experience in science, something they could not get from their sciences classes, and that they were positively motivated to do so.

Emotional involvement in what is being learned. A reoccurring theme that emerged when the participants talked about the days leading up to the launch and the day of the launch, was the association of emotions, such as; excitement anxiety and stress, with their learning and with their preparing, carrying out and adjusting their plans. From my position as science teacher-GSBC supervisor, they appeared to better remember and draw upon knowledge and skills when their learning was accompanied with high levels of emotional involvement.

After re-watching several videos of the launch day, there is unequivocal evidence of high emotions when students use swear words to release stress. It is undeniable that the four participants were emotionally involved in what they were doing. Although they reported being stressed and experiencing anxiety, they managed to take responsibility, to work through the challenges, and to have an elevated personal enjoyment of the GSBC. I argue that being emotionally involved influenced not only their personal enjoyment but also their overall learning and impacted their attitudes towards science in a positive way. These findings are consistent with the Raffaelli and Villegas (2018) study in which they found youth learning how to deal with their emotions while caring out a goal in the program in which they were involved. Moreover, the Raffaelli and Villegas (2018) study showed more positive emotions being associated with OST programs, including STEM programs and project-based learning. Finally, recall the discussion under the heading

‘Affective Attitudes Towards Science’ in Chapter 2, and how such attitudes are associated with one’s feelings, beliefs and values about science and the activities they are doing at the time that require “students to build on their prior knowledge” (Lewandowski, Finkelstein, & Zwickl, 2013) while being challenged to think critically and to be creative (Osborne, Collins, & Simon, 2003). The data from this study substantiate these published results.

Stereotypes of physics and STEM careers. Although the participants involved in the study had a predilection for science and engineering and chose careers in these areas at the post-secondary level, they remember the GSBC has having a positive impact on students’ attitudes about physics and STEM careers. Participant A, for example, talked about how the GSBC positively changed a Grade 9 student’s perception of physics: S/He “actually loved physics afterwards.” In this same context, Participant A expressed the belief that the GSBC “helps a lot of kids consider physics as a career.” Participant C spoke about the GSBC as a great experience for STEM majors as it showed them how they can directly apply their classroom knowledge to real world applications. Participant C described the experience as, “the opportunity to learn hands-on skills, group skills, and some things [that] in the classroom you don’t get.” Moreover, Participant B, who shared how s/he had pictured scientists as being people working in a clean environment, dressed in lab coats, looking serious and writing long formulas on whiteboards, discovered that the GSBC was not like the stereotypes s/he had in mind.

These findings affirm the positive impact of the GSBC students’ views of STEM careers. This corroborates the results of the Afterschool Alliance (2011) study and the research of Almarode and colleagues (2012 where OST science programs contributed to improving students’ attitude towards science and acted as a conduit for STEM career paths.

As far as stereotypes are concerned, the research literature suggests that they emphasize and exaggerate the characteristics of a social group that make them different from ordinary citizens (Tintori, 2017). Such stereotypic characteristics of scientists (see pages 38-39), particularly those portrayed in media that go unchallenged in K-12 school science, tend not to foster in students an interest in science, an interest in becoming a scientist, or in students seeing themselves as scientists. Fortunately, there is data, similar to the above statement from Participant B, showing that out-of-school time STEM programs and projects provide students with a better sense of who scientists are and what scientists do in the real-world (Afterschool Alliance, 2011 ASPIRES Project, 2014; Duran et al., 2014; Kristnamurthi et al., 2014).

Perceiving school science subjects as content and content specific with limited, if any, understanding of NOS. An important finding that surfaced in two of the four interviews was Participants C and D's change in perception towards aspects of the nature of science. Participant D talked about how the GSBC taught her/him that science does not happen in isolation and that errors or oversights are part of the scientific process. In making such "mistakes" it is possible to learn, revaluate, and come up with new ideas to try. Recall the excerpt in Chapter 4: "What I learned from the whole experience was that science doesn't happen in one room, from day to day classroom setting…What I also learned was we can perform a lot of science outside in an actual environment...and it's okay to make mistakes" (Participant D). Participant C stated that the GSBC shows students that their science subjects, although taught in isolation, can all be applied to projects that have real world applications. S/He said: "I think it's opportunities like this that really shed light on that. Like, you know how important it is to the technical knowledge, but how probably even more important it is to be able to apply and know it, not just memorize it" (Participant C).

These findings are consistent with the positive impact STEM and science-based learning projects can have on students' views on the NOS (Chang et al., 2011). Learning experiences like the GSBC give students a better idea of how scientists and engineers think and apply knowledge to real world problems and issues.

Personal growth within OST STEM-based learning projects. An important outcome identified in interviews with Participants A, C and D was the personal growth each attributed to taking part in the GSBC. Recall the quote from Participant A in Chapter 4 (p. 69) where s/he is describing the role s/he repeatedly procured/commandeered for group projects. It was the GSBC club that taught her/him to listen to others and to know how to listen so that it was possible to take the ideas of other members into account. If this wasn't done, s/he recognized that those members who were silenced would not be invested in the project or launch. S/he made sure that everybody had an opportunity to share, discuss ideas and contribute to the final decision.

Participant C found that the biggest challenge was GSBC members coming to consensus when a decision had to be made. As described in Chapter 4 (p. 70), members of the GSBC were initially so excited and anxious that it was difficult to listen. As time passed, s/he realized the importance of wait time. It was "waiting things out" that made listening, the sharing of ideas and decision making possible.

Participant D was involved with the 2016 GSBC as a student in Grade 11 physics and 2017 GSBC while in Grade 12. S/He mentioned becoming more of a leader during the 2017 GSBC by using the experiences of the previous year. Recall from Chapter 4 how Participant D became a leader in the 2017 GSBC attempting to motivate students by listening and considering their ideas in the payload design (p. 70).

This finding, focused on participants' personal growth, aligns with what the literature reports on OST programs that were initially designed to positively influence personal development and to promote social and emotional growth (Krishnamurthi et al., 2014). According to Schwartz and Noam (2016), the more recent science and STEM after school and out-of-school programs draw aspects from museum science, more focused on personal growth, and school science, more focused on academics. Thus, it's not surprising to find the positive impact of the GSBC, an out-of-school time program on the personal growth of three participants.

Participants' Perceptions of How Science is Conducted Following the 2016 GSBC

Trial and error as part of the process of science. A finding worthy of further discussion is Participant D's realization that mistakes are part of the scientific process. Mistakes with regards to the GSBC incorporate unforeseen design errors (e.g., associated with the payload) and measurement errors (e.g., testing the GPS for signal, tracking and navigation accuracy errors) particularly on the launch day itself. Prior to involvement in the GSBC, students registered for science classes at Maples Collegiate had only encountered laboratory exercises and science activities with set procedures and established learning outcomes. Participant D showed a change in her/his perception of the nature of science (NOS) related to the manner in which science is conducted by scientists. S/He described classroom science labs as following a predetermined procedure so students will be successful in completing an assigned task. Yet, "…in the actual Space Balloon Challenge what we learn as a team was that in science it's okay to make mistakes" (Participant D). In technological and engineering fields, this is the reason for testing prototypes against criteria that determine success. As you may recall, Participant D also mentioned how scientists and engineers must be able to think on their feet, make changes in the moment, and persevere. S/He stated:

> You must be able to work around, come with different ideas, not just one, [but] come with separate ideas, so if one doesn't work maybe the other one will work. And, perseverance, I think that is one of the biggest thing when it comes down to anything.

Similar to Participant D, Participant B also showed a change in perception about NOS and the work of scientists. Although s/he did not specifically mention mistakes her/his focus was experimental work. S/he said: "There's no definitive formula that you have to follow in order to make this thing take off the ground…and I guess in experiments, it's not supposed to go all to plan, to go smoothly."

What these two participants came to realize about the process of science, through a STEM based-learning activity, aligns with a 2011 publication of Chang and colleagues. They describe how science in project-based learning experiences helps students to develop a positive view of NOS and a more accurate understanding of scientific endeavours outside of classrooms, where the testing of hypotheses generally involves a great deal of trial and error.

Problem solving when suddenly faced with more than one issue. An important element often lacking in science classrooms is learning activities that incorporate multiple interacting variables that present effects/outcomes requiring immediate diagnosis and judgment for resolution. As one example, in my teaching the physics of kinematics problems I give students to solve tend to ignore friction and air resistance. When experiencing the GSBC, these external variables, such as wind or rain, must be taken into account. In Chapter 4, Participant A mentions that you do not find these external variables in classroom labs: "This [project] got to look into an area, which we sort of ignore in physics, which is different variables that we never considered."

Participant B also commented on these external variables and the problem solving that must be carried out when variables actually come into play. S/he said: "When you're in a classroom, you're just sitting there. You could solve a problem on paper and its ideal conditions, like, there's no weird variables that are given… When you're out there [launching a weather balloon on a field], it's like you have a general plan, but you have to improvise more times."

For Participants A and B, there is a change in perception of NOS and how science is conducted as a result of their experiencing the GSBC. Herro amd Quigley (2006) discuss how science project-based learning positively impacts students' views of the NOS. Moreover, these opportunities provide students with a much better sense of how science is more complicated and ingenious in the real word where conditions are seldom if ever ideal.

Importance of communication within the GSBC team. The topic of teamwork was identified in each of the four interviews. A crucial aspect of teamwork was the theme of communication. Since the four participants were in Grade 11 or Grade 12, I presumed they would get along well with one another and with other members of the GSBC. This was not always the case. From my observations as team supervisor, I am aware of numerous times when senior students would get into debates about how the payload should be built and where items should be placed inside the payload. I also remember a Grade 9 student challenging a senior student at every turn. Clearly s/he was not about to be pushed around by a senior student advising her/him on what to do and how to do it. These differences in opinion and personality are factors the members of the 2017 GSBC had to overcome in order to work collaboratively as a team. In addition, I observed the students using communication and negotiation skills to work through the challenges of decision making. This did not come easy to them. They overcame these obstacles by listening to each other, taking everyone's ideas into consideration, and forming a consensus to arrive at final decisions. Recall this narration from Chapter 4: "Everybody has to be on the same page, and to get on the same page…requires a pretty high level of communication. I found that a big part of what the team was…" (Participant C). Participant C goes on to discuss how having a higher level of communication aided in everyone considering and valuing each other ideas when coming to a consensus.

The participants came to realize the importance of communication in the process of science. Jiménez-Aleixandre and Erduran (2007) claim that discourse, particularly argumentation from evidence in the construction of scientific knowledge and argumentation as persuasion in socially mediated activities, is an integral part of science and should be incorporated in school science education. According to Lewandowski et al. (2013) STEM based-learning activities give students the opportunity to understand how and why scientists do science the way they do. One infers that this includes an understanding of the discourse processes in science and scientific inquiry.

Application of integrated science content knowledge in STEM projects. Member checking. The phrase "integrated science content knowledge" is an attempt to name the utilization of knowledge from several, not just one, of the disciplines of the natural sciences that are generally part of school curricula (e.g., astronomy, biology, chemistry, Earth science, physics). Participation in the GSBC required the application of integrated science content knowledge. GSBC members were faced with problems composed of multiple factors/variables that influenced what they were attempting to accomplish. Such situations, whether building the payload, testing the GPS, or launching the payload, demanded that they draw upon content knowledge from several science disciplines. Participant C described this best when talking about the GSBC providing contexts for what they have learned in science courses:

> …when you experience something like the Global Space Balloon Challenge, in order to understand how it works you have to apply that knowledge…That's when students really understand why they're learning what they are learning…It gives them the opportunity to

realise that [the] science, math they're learning in school does have significance and an importance.

Participants in the study revealed how they became aware of the differences between traditional classroom labs and the unstructured, unpredictable nature of the GSBC. They recognized that laboratory exercises in school science are constructed in such a way that they will neither fail nor experience the need to problem solve by taking into account the multiple variables at play. Hodson (2009) advocates that classroom science needs to incorporate actually learning about science and not simply focus on learning science content. The process of science uses commutation, creative and critical thinking skills that includes understanding how science fits into technology and society as a whole (Hodson, 2009). In order to improvise and think on their feet, the participants had to apply what they had learned in the various science courses they had completed or were currently registered in. The application of their science knowledge aided in showing the participants how interconnected their science subjects actually are and, more importantly, how this knowledge can be used in the world outside the classroom.

Summary of Chapter Five

It's clear the GSBC incorporates STEM skills and engages students in experiences that bring to light aspects of the nature of science that aren't often pointed out or discussed in school science lessons. Science, technological and engineering skills such as working collaboratively in a team, intercommunication, thinking critically and creatively to solve problems, as well as applying knowledge from several disciplines are incorporated in the Cluster Zero outcomes of the Manitoba science curriculum. Cluster Zero is comprised of skills and attitudes that focus on the development of scientific practices and work habits, engineering practices and work habits, and informed decision making in the context of science, technology, society and environment (STSE) issues. These skills and attitudes were developed as learning outcomes, which in combination with content knowledge outcomes would assist Manitoba students in achieving scientific literacy; the aim of science education in Manitoba. (Manitoba, Education, 2001).

As a science teacher who has taught Grades 9 through 12 science, I know how challenging it is to address all of the knowledge, skill and attitude outcomes in Manitoba science curricula. Similar to many high school science teachers in the province, I struggle to teach the mandated units in a particular science discipline in the scheduled time allotted. Added to this time constraint are numerous interruptions throughout the school year such as professional development days, sick days, and students who, for a multitude of reasons, miss class. The participants in the GSBC acknowledge that their STEM based-learning activity was more engaging than regular classroom work. However, it is unclear from the student's responses, given the interview questions posed, that they understand the constraints teachers face when it comes to Manitoba Education's mandated science curriculum and incorporating STEM-based learning activities, like the GSBC, in the classroom. We would like engage al students in what we teach and have opportunities for open-ended activities and laboratory work, practically sense the study has shown that such opportunities lead to positive attitudes towards science and a more accurate understanding of what scientists do.

Chapter Six – Conclusions and Limitations

The document *An action plan for science education in Manitoba* (Manitoba Education and Training, 2011a) calls for further developing science literacy, proficiency, problem solving, critical thinking skills and improving students' interests in science and technology studies and "the wide variety of careers related to science, technology, and the environment." Although not explicitly stated, it is not unreasonable to include the study of engineering (the "design process" in Manitoba's science curriculum documents) and the study of mathematics (the language of science) and, thus, STEM (science, technology, engineering, mathematics) careers in the aims for science education listed immediately above. The fact that the second aim for science education is to "enable students to use science and technology to acquire new knowledge and solve problems, so that they may improve the quality of their own lives and the lives of others" adds credibility to this presumption.

Gibillisco (2013) lists seven standards of practice/skill sets that STEM educators have identified. These include: "learn and apply content, integrate content, interpret and communicate information, engage in inquiry, engage in logical reasoning, collaborate as a team, and apply technology appropriately." In this light, the 2016 GSBC, a school year long out-of-school time (OST) project-based learning experience is considered an excellent example of STEM education based on a real-life situation.

Findings of this case study strongly suggest that the GSBC develops critical thinking, team-building, communication and problem-solving skills, and improves students' ideas about STEM careers and how the content of their school science subjects can be applied in real world applications. In addition, the GSBC was found to have an overall positive impact on participants' attitudes towards science and their perceptions of how scientific and design engineering work is carried out in society.

Participating students recounted how the GSBC challenged their perceptions of physics and provided insight into the importance of school science curriculum in preparing them for a more in-depth experience with STEM learning.

Students who had participated in the GSBC revealed how the experience developed leadership skills and friendships that may never have formed without the Maples Collegiate Science Club and the work of its members on the GSBC.

A key finding repeatedly disclosed in the interviews with all four participants was the memorable non-traditional experience of preparing for the GSBC and the day of the actual challenge. When recalling the launch day, all four reported feelings of excitement, anxiety and stress. As an educator I know how difficult it is to get students to participate in a 60 to 90 minute lesson, construct new knowledge, and store this knowledge in long term memory in a manner that enables it to be quickly retrieved and successfully applied when prompted. Participants' recollection of the full day GSBC launch and retrieval of the payload affirms the importance of learners having an emotional investment in their learning. Not only did the GSBC have a positive impact on students' development of skills and knowledge, it is also an example of how the application of knowledge and skills are impacted by feelings and attitude. Students from all school teams participating in the GSBC were challenged by the novel problems they encountered, but everyone, not just the team from Maples Collegiate, was focused, engaged and having fun.

Findings in this case study also showed that the GSBC influenced participants' perceptions of the methods by which the knowledge of science is constructed and applied. It challenged them to communicate, to function collaboratively as a team, and to draw from pervious knowledge in order to critically think, problem solve, and creatively develop new ideas and approaches for a successful launch of the payload. These valuable aspects of STEM-based learning projects are not reported in studies focused on traditional classroom laboratory exercises at the high school level (Cracolice & Monteyne, 2014). The literature does reveal that STEM-based learning projects positively impact students' views of the nature of science through non-traditional laboratory activities (Lewandowski et al., 2013) and the real-world application of science (Herro & Quigley, 2016). As, Chang and colleagues (2011) argue, project-based learning provides students with an experience that is similar to how science is conducted in the workplace. This was unquestionably the case for the four research participants who were part of the Maples Collegiate 2016 Global Space Balloon Challenge.

Limitations

There are limitations to the research. First, it has a very small sample size. A larger number of student participants would have provided a richer and possibly more comprehensive description of student experiences with the GSBC. Second, the four participants interviewed all had a predilection for the sciences, and each had taken a variety of science course offerings at Maples Collegiate. Thus, the research study can not look more deeply into the impact of the GSBC on students who did not have such a predisposition. Third, owing to the small number of participants, the study does not look at how gender of students might influence the findings, an important aspect given the disinterest in STEM of many girls and women identified in the literature. Fourth, it's important to consider as a limitation the social and economic status of the four research participants, as all come from supportive families that are economically sound. Socio- economic status, a significant variable associated with the closing the achievement gap reported by Dietel and Juang (2011), Krishnamurthi et al. (2014), and. Schwartz & Noam (2016) in the context of to after-school and OST programs, could have had an impact on the findings and conclusions drawn. Finally, although as researcher I have attempted to keep my biases at bay, I could possibly be seen as a limitation given my position as the participants' Maples Collegiate Science Club leader, GSBC supervisor, and past teacher of Physics 30S and/or Physics 40S and/or Astronomy 31G.

As alluded to above, even though the 2016 GSBC is revealed as having a positive impact on high school students' attitudes towards science and their preconceptions of how science is carried out in the scientific community, more research is needed to fully grasp the full impact of the GSBC STEM based-learning experiences. Questions requiring answers have to do with the following:

- The type of integrated STEM based-learning experience for high school students. How does a project focused on physics, mathematics, engineering, and technology like the 2016 GSBC compare with STEM projects that incorporate some other combination of subjects (e.g., agrobiology or geophysics or physical organic chemistry and mathematics, technology, and engineering)?
- The scheduling of STEM-based learning experiences for high school students. What are the consequences of scheduling a project during school hours (e.g., as part of a timetabled science course like the Maples Collegiate 2015 GSBC), after-school hours, out-of-school time, or out-of-school time and as part of a non-school club (unlike the Maples Collegiate 2016 Science Club)? Moreover, what are the consequences of scheduling the project to run for days, versus weeks, months, or a year?
- As mentioned in the limitations above, what is the impact of STEM-based learning experiences on:

  a) high school students who don't like studying science and have never listed science as one of their favourite school subjects;

b) high school students of different genders;

c) high school students living with family members who are ignorant of the benefits of science and STEM careers or family members who are cognizant of the benefits of science and STEM careers, and;

d) high school students living in low income families and high school students living in low-income families.

Afterword

When I began to develop the proposal for this thesis research study, I had supervised two different GSBC teams and had what I considered to be a fairly good idea of the benefits of the Global Space Balloon Challenge for students. The literature review provided me a language for what I had observed and had failed to recognize. It also made me aware of the scarcity of research on STEM-based project learning at the high school level and on the impact of the GSBC learning experience on attitudes to science and awareness of how science is conducted in society by the community of scientists. This was the gap that I identified as the basis for the study.

Although it would have been ideal to have received positive responses from all ten students invited to participate in the study, the four who gave consent brought to light, through their recollections of the 2016 GSBC, findings reported for after-school and out-of-school time science and STEM programs. Their responses to the interview questions corroborate what has been reported in these programs for elementary and post-secondary students. The GSBC, from the perspectives of these four student participants, is unquestionably an outstanding project for achieving more positive attitudes towards science and STEM, opportunities for personal social growth and behaviour, and for deepening understanding of aspects of the nature of science, particularly accurate and considerate communication, collaborative team work, creative and critical thinking in light of the content knowledge available, trial and error hypothesis testing, perseverance, and the application of technology.

In light of these findings and the action plan for Kindergarten through Grade 12 science education in Manitoba, one could argue that the best way of achieving these goals for scientific literacy by Grade 10, the final year for which science is required by Manitoba Education, would be to incorporate activities like the GSBC in the learning experiences designed for all students. Rather than four science clusters in Grades 1 through 10, mandate 3 science clusters and one cluster for a choice of STEM projects that require the application of the knowledge developed at a specific grade level. Given Manitoba's spiral science curriculum where topics come back at higher grade levels with more complex content, there would not be a loss in the science content knowledge and skills to which students are currently exposed. Moreover, with choice, small groups of students would likely be emotionally invested with many of the benefits mentioned by the four 2016 GSBC interviewees. This aligns with previous studies reviewed in Chapter 2 that point to the necessity for STEM projects centred on science and engineering to focus on personal interest (Almadore et al., 2014) and for students participating in such programs "to learn science and obtain science related knowledge from practical [rather than cookbook] experiments" (Chang et al, 2011).

References

Abd-El-Khalick, F. (2014). The evolving landscape related to assessment of nature of science. In N. Lederman & S. Abell (Eds.), *Handbook of research on science education,* vol.2 (621-650). New York, NY: Routledge.

Abd-El-Khalick, F., & Boujaoude, S. (1997). An exploratory study of the knowledge base for science teaching. *Journal of Research in Science Teaching, 34*, 673-699.

Abd-El-Khalick, F., Bell, R., & Lederman, N. (1998). The nature of science and instructional practice: Making the unnatural natural. *Science Education, 82*(4), 417-437.

Abd-El-Khalick, F., Lederman, N., Bell, R., & Schwart, R. (2001). Views of nature of science questionnaire (VNOS): Toward valid and meaningful assessment of learners' conceptions of nature of science. Retrieved from https://archive.org/stream/ERIC_ED472901/ERIC_ED472901_djvu.txt

American Association for the Advancement of Science (1989). Project 2061: Science for all Americans. Washington, DC: Author.

Afterschool Alliance (2011). STEM Learning in Afterschool: An Analysis of Impact and Outcomes. Retrieved from: http://www.afterschoolalliance.org/STEM-Afterschool-Outcomes.pdf

Afterschool Matters. (2010). Retrieved from: http://www.niost.org/pdf/afterschoolmatters/ASM_June2010.pdf

Aikenhead, G., & Ryan A. (1992). The development of a new instrument: Views on science-technology-society (VOSTS). *Science Education, 76*, 477-491.

Allchen, D. (2013). *Teaching the nature of science: Perspectives and resources*. St. Paul, MN: SHIPS Education Press.

Almarode, J. T., Dabney, K. P., Hazari, Z., Miller-Friedmann, J. L., Sadler, P. M., Sonnert, G., & Tai, R.H., (2012). Out-of-School Time Science Activities and Their Association with Career Interest in STEM. *International Journal of Science Education, Part B, 2*(1), 63–79. https://doi.org/10.1080/21548455.2011.629455

Alters, B. (1997). Whose nature of science? *Journal of Research in Science Teaching, 34*(1), 39-55.

Amin, H. U., Malik, A. S., Saad, M. N. M., & Tyng, C. M., (2017). The influences of emotion on learning and memory. *Frontiers in Psychology*, *8*(1454), 1-22. https://doi.org/10.3389/fpsyg.2017.01454

ASPIRES Project (2014). ASPIRES: Young people's science and career aspirations, age 10-14. London: King's College London. Retrieved from www.kcl.ac.uk/sspp/departments/educaiton/research/aspires/ASPIRES-final-report-December-2013.pdf

Barmby, R., Jones, K., & Kind, P. (2007). Developing attitudes towards science measures. *International Journal of Science Education, 29*(7), 871-893. doi:10.1080/09500690600909091

Beck-Winchatz, B., & Hike, B. (2015). Near-Space Science: A ballooning project to engage students with space beyond the big screen. *The Science Teacher, 82*(1), 29-36. Retrieved from http://uml.idm.oclc.org/login?url=http://search.proquest.com.uml.idm.oclc.org/docview/1720065873?accountid=14569

Bergman, E., de-Feijter, J., Frambach, J., Godefrooij, M., Slootweg, I., Stalmeijer, R., & van der Zwet, J. (2012). AM last page: A guide to research paradigms relevant to medical education. *Academic Medicine, 87*(4), 545.

Bodzin, A., & Gehringer, M. (2001). Breaking science stereotypes. *Science and Children, 39*(1), 36-41.

Boys & Girls Clubs of Canada. (2011). After school: The time of a child's life. Retrieved from https://www.bgccan.com/en/AboutUs/PublicPolicy/Documents/After%20School%20Paper_ENG_Final.pdf

Brickman, P., & Lovelace, M. (2013). Best practices for measuring students' attitudes toward learning science. *CBE – Life Sciences Education, 12*, 606-617. doi:10.1187/cbe.12-11-0197

Bruce-O'Connell, M. (2012). Newfoundland and Labrador students receive innovative science-based learning program with Hibernia's investment in Let's Talk Science. Retrieved from http://www.newswire.ca/news-releases/newfoundland-and-labrador-students-receive-innovative-science-based-learning-programs-with-hibernias-investment-in-lets-talk-science-509721681.html

Buffler, A., Lubben, F., & Ibrahim, B. (2007). Profiles of freshman physics student's views on the nature of science. *Journal of Research in Science Teaching, 46(*3), 248-264. doi:10.1002/tea.20219

Campbell, P., & Cleveland-Innes, M. M. (2012). Emotional presence, learning, and the online learning environment. *International Review of Research in Open and Distance Learning, 13*(4), 269–292. https://doi.org/10.1016/j.iheduc.2011.10.001

Canadian Institutes of Health Research, Natural Sciences and Engineering Research Council of Canada, & Social Sciences and Humanities Research Council of Canada. (2014). *Tri-Council Policy Statement: Ethical conduct for research involving humans*. *Secretariat on Responsible Conduct of Research*. https://doi.org/1

Chambers, D. (1983). Stereotypic images of the scientist: Draw-a-scientist test. *Science Education, 67*(2), 255-265).

ChanLin, L. J. (2008). Technology integration applied to project-based learning in science. *Innovations in Education and Teaching International*, 45(1), 55–65.

Chang, C-C., Chen, W-P., Lou, S-J., Tseng, K-H. (2011). Attitudes towards science, technology, engineering and mathematics (STEM) in a project-based learning (PjBL) environment. *International Journal Technology Des Education*, 23, 98-102. doi 10.1007/s10798-0011-9160-x.

Clough, M. (1997). Strategies and activities for initiating and maintaining pressure on students' naïve ideas concerning the nature of science. *Interchange, 28*(2-3), 191-2054.

Clough, M. (2009). We all teach nature of science – Whether accurately or not. *Iowa Science Teachers Journal*, *35*(2), 2-3.

Coburn, W., & Loving, C. (2002). Investigation of preservice elementary teachers' thinking about science. *Journal of Research in Science Teaching, 39*(1), 1061-1031.

Coleman, J., & Mitchell, M. (2014). Active learning in the atmospheric science classroom and beyond through high-altitude ballooning. *Journal of College Science Teaching, 44*(2), 26-30. Retrieved from: http://uml.idm.oclc.org/login?url=http://search.proquest.com.uml.idm.oclc.org/docview/1651863024?accountid=14569

Cracolice, M., & Monteyne, K. (2004). What's wrong with cookbooks? A reply to Ault. *Journal of Chemical Education, 81*(11), 1559-1560.

Creswell, J.W. (2007). *Qualitative inquiry and research design: Choosing among five approaches* (2nd ed.). Thousand Oaks, CA: Sage Publications, Inc.

Creswell, J. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed.). Thousand Oaks, CA: SAGE Publications, Inc.

Deng, F., Chai, C., Chen, D-T., & Tsai, C-C. (2011). Students' views of the nature of science: A critical review of research. *Science Education, 95*(6), 961-999. doi:10.1002/sce.20460

Dietel, R., & Huang, D. (2011). Making afterschool programs better. (CRESST Policy Brief). Los Angeles, CA: University of California.

Driver, R., Leach, J., Millar, R., & Scott, P. (1996). *Young people's images of science*. Buckingham, UK: Open University Press.

Duran, M., Höft, M., Lawson, D., Medjahed, B., & Orady, E. (2014). Urban high school students' IT/STEM learning: Findings from a collaborative inquiry- and design-based afterschool program. *Journal of Science Education and Technology, 23*, 116-137

Education, Manitoba: Senior 1 Science (2001). Retrieved from: http://www.edu.gov.mb.ca/k12/cur/science/outcomes/s1/full_doc.pdf

Eagly, A. (1992). Uneven progress; Social psychology and the study of attitudes. *Journal of Personality and Social Psychology, 63*(5), 693-710.

Eagly, A., & Chaiken, S. (1993). *The psychology of attitudes*. Fort Worth, TX: Harcourt, Brace, Jovanovich.

Eagly, A., & Chaiken, S. (2007). The advantages of an inclusive definition of attitude. *Social Cognition, 25*(5), 582-602.

Francis, L., & Greer, J. (1999). Measuring attitude towards science among secondary school students: The affective domain. *Research in Science & Technology Education, 17*(2), 219-226. Retrieved from: http://www.tandfonline.com/doi/abs/10.1080/0263514990170207

Gilbert, J., Rennie, L., Stocklmayer, S. (2010). The roles of the formal and informal sectors in the provision of effective science education. *Studies in Science Education*. 46(1), 1-44. doi: 10.1080/03057260903562284

Gilillisco, S. (2013). Definition: STEM (science, technology, engineering, and mathematics). Retrieved from https://whatis.techtarget.com/definition/STEM-science-technology-engineering-and-mathematics.

Global Space Balloon Challenge. (n.d.). Retrieved from https://www.balloonchallenge.org/teams

Halpren, R. (2002). A different kind of child development institution: The history of after-school programs for low-income children. *Teachers College Record, 104*(2), 178-211. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.581.1426&rep=rep1&type=pdf

Herro, D., & Quigley, C., (2016). "Finding the Joy in the Unknown": Implementation of STEAM teaching practices in middle school science and math classrooms. *Journal of Science Education and Technology*, 25(3), 410-426. doi 10.1007/s10956-016-9602-z

Hillman, S., List, H., Tilburg, C., & Zeeman, S. (2016). My attitudes toward science (MATS): The development of a multidimensional instrument measuring students' science attitudes. *Learning Environment Research, 19*, 203-219. doi:10.1007/s10984-016-9205-x

Hodson, D. (2003). Time for action: Science education for an alternative future. *International Journal of Science Education*, *25*(6), 645–670. https://doi.org/10.1080/09500690305021

Hodson, D. (2008). *Towards scientific literacy: A teachers' guide to the history, philosophy and sociology of science*. Rotterdam, NL: Sense Publishers.

Hodson, D. (2009). *Teaching and learning about science: Language, theories, methods, history, traditions and values*. Rotterdam, NL: Sense Publishers.

Hodson, D. (2014a). Learning science, learning about science, doing science: Different goals demand different methods. *International Journal of Science Education*, *36*(15), 2534-2553.

Hodson, D. (2014b). Nature of science in the science curriculum: Origin, development, implications and shifting emphases. In M. Matthews (Ed.), *International handbook in history, philosophy and science teaching* (pp. 911-970). Springer

Hogan, K. (2000). Exploring a process view of students' knowledge about the nature of science. *Science Education, 84*(1), 51-70.

Jiménez-Aleixandre, M. P., & Erduran, S. (2007). Argumentation in science education: An overview. In S. Erduran and M. P. Jiménez-Aleixandre (Eds), *Argumentation in science education*., 3-27. Dordrecht, Springer.

Karaman, S., & Celik, S. (2008). An exploratory study on the perspectives of prospective computer teachers following project-based learning. *International Journal of Technology and Design Education*, 18(2), 203–215.

Kim, B. (2001). Social constructivism. In M. Orey (Ed.), *Emerging perspectives on learning, teaching, and technology*. Retrieved from http://epltt.coe.uga.edu/index.php?title=Social_Constructivism

Krapp, A., & Prenzel, M. (2011). Research on interest in science: Theories, methods, and findings. *International Journal of Science Education, 33*, 27-50.

Krishnamurthi, A., Ballard, M., & Noam, G. (2014). Examining the impact of afterschool STEM programs. Retried from: http://afterschoolalliance.org/ExaminingtheImpactofAfterschoolSTEMPrograms.pdf

Leach, L., Millar, R., Ryder, J., & Séré, M-G. (2000). Epistemological understanding in science learning: The consistency of representations across contexts. *Learning and Instruction, 10*(6), 497-527.

Lederman, N. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching, 29*(4), 331-359. doi:10.1002/tea.3660290404

Lederman, N. (2007). Nature of science: Past, present, and future. In S. Abell & N. Lederman (Eds.), Handbook of research on science education (pp. 831-879). Mahwah, NJ: Erlbaum.

Lederman, N., Abd-El-Khalick, F., Bell, R., & Schwartz, R. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching, 39*(6), 497-421.

Lederman, N., Wade, P., & Bell, R. (1998). Assessing the nature of science: What is the nature of our assessments? *Science and Education, 7*, 595-615.

Lewandowski, H., Finkelstein, N., & Zwickl, B. (2013). *A Framework for Incorporating Model-Based Inquiry into Physics Laboratory Courses.* Retrieved from: http://www.colorado.edu/physics/EducationIssues/zwickl/Resources/Zwickl_framework_for_model-based_inquiry.pdf

Little, P., Wimer, C., & Weiss, H. (2008, February). After school programs in the 21st century: Their potential and what it takes to achieve it. *Issues and Opportunities in Out-of-School Time Evaluation Brief* No. 10. Cambridge, MA: Harvard Family Research Project. Retrieved from http://www.hfrp.org/publications-resources/publications-series/issues-and-opportunities-in-out-of-school-time-evaluation/after-school-programs-in-the-21st-century-their-potential-and-what-it-takes-to-achieve-it

Liu, A. (2010). *Using and developing measurement instruments in science education: A Rasch modeling approach*. Charlotte, NC: Information Age Publishing.

Lockheed Martin Canada. (2017). STEM education. Retrieved from http://www.lockheedmartin.ca/ca/who-we-are/in-the-community/stem-education.html

Logan, B. (2014). Launching the first global space balloon challenge. Retrieved from http://www.engin.umich.edu/college/about/news/stories/2014/february/global-space-balloon-challenge

Lyon, G., & Jafri, J. (2010). Project Exploration's Sisters4Science: Involving urban girls of color in science out of school. *Afterschool Matters, 11*, 15-23.

Manitoba Education, Citizenship and Youth (2005). *School Partnerships*. *Learning*.

Manitoba Education, Citizenship and Youth (2006). *MB: Rethinking classroom assessment with purpose in mind. Assessment for learning, assessment as learning, assessment of learning.* Retrieved from http://www.wncp.ca/media/40539/rethink.pdf

Manitoba Education and Training. (2011a). An action plan for science education in Manitoba: A rationale for the action plan. Retrieved from http://www.edu.gov.mb.ca/k12/cur/science/action_plan/rationale.html

Manitoba Education and Training. (2011b). An action plan for science education in Manitoba: Goals for science education. Retrieved from http://www.edu.gov.mb.ca/k12/cur/science/action_plan/goal.html

Manitoba Education Training and Youth. (2001). *Positive School Climate - What is a Positive School Climate? Towards Inclusion - From Challenges to Possibilities: Planning for Behaviour*. Retrieved from http://www.edu.gov.mb.ca/k12/specedu/beh/pdf/BEH_Document.pdf

Manitoba Education and Youth. (2003). *Independent Together Supporting the Multilevel Learning Community*.

Martin-Hansen, L. (2002). Defining inquiry. *The Science Teacher, 69*(2), 34-37.

Matthews, M. (1994). *Science teaching: The role of history and philosophy of science*. New York, NY: Routledge.

McComas, W. (1998). The principle elements of the nature of science: Dispelling the myths. In W. McComas (Ed.), *The nature of science in science education: Rationales and strategies* (pp. 41-52). Dordrecht, DE: Kluwer Academic Publishers.

McComas, W., & Olson, J. (1998). The nature of science in international science education standards documents. In W. McComas (Ed.), *The nature of science in science education: rationales and strategies* (pp. 41-52). Dordrecht, NL: Kluwer Academic press.

McComas, W., Almazroa, H., & Clough, M. (1998). The nature of science in science education: An introduction. *Science and Education, 7*, 511-532.

McKay, M. (2013). Imperial Oil funds STEM education. Retrieved from http://justmeans.com/article/imperial-oil-funds-stem-education

Merriam, S., & Tisdell, E. (2016). *Qualitative research: A guide to design and implementation* (4th edition). San Francisco, CA: John Wiley & Sons.

Monk, M. & Osborne, J. (1997). Place the history and philosophy of science on the curriculum: A model for the development of pedagogy. *Science Education, 81*, 405-424.

Moreno, N., Newell, A., Tharp, B., Vogt, G., & Zientek, L. (2015). *Students' Attitudes Towards Science as Predictors of Gains on Student Content Knowledge: Benefits of an After-School Program. School Science and Mathematics, 115*(5), 216-225. doi:10.11/ssm.12125

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

Newton, L., & Newton, D. (1998). Primary children's conceptions of science and the scientist: Is the impact of a National Curriculum breaking down the stereotype? *International Journal of Science Education, 20*(9), 1137-1149.

Osborne, J. (2002). Science without literacy: A ship without a sail? *Cambridge Journal of Education, 32*(2), 201-218.

Osborne, J., Collins, S., Reatcliffe, M., Millar, R., & Duschl, R. (2003). What "ideas about science" should be taught in school science? A Delphi study of the expert community. *Journal of Research in Science Teaching, 40*(7), 692-720.

Osborne, J., Simon, S., & Collins, S (2003). *Attitudes towards science: a review of the literature and its implications*. *International Journal of Science Education, 25*(9), 1049-1079. doi:10.1080/0950069032000032199

Pomeroy, D. (1993). Implications of teachers' beliefs about the nature of science: Comparison of the beliefs of scientists, secondary science teachers, and elementary teachers. *Science Education, 77*, 261-278.

Potvin, P., & Hasni, A. (2014). Interest, motivation and attitude towards science and technology at K-12 levels: A systematic review of 12 years of educational research. *Studies in Science Education, 50*(1), 85-129. Retrieved from https://www.usherbrooke.ca/creas/fileadmin/sites/creas/documents/Publications/Articles_scientifiques/Interest__motivation_and_attitude_Potvin-Hasni_2014.pdf

Raffaelli, M., & Villegas, E. (2018). Experiencing and Learning About Emotions: A Longitudinal Analysis of Youth Program Participants. *Journal of Youth and Adolescence*, *47*(8), 1684–1696. https://doi.org/10.1007/s10964-018-0885-7

Ritz, J. M., & Fan, S. C. (2014). STEM and technology education: international state-of-the-art. *International Journal of Technology and Design Education*, *25*(4), 429–451. https://doi.org/10.1007/s10798-014-9290-z

Roberts, D. (2007). Scientific literacy/Science literacy. In S. Abell & N. Lederman (Eds.) *Handbook of research on science education* (pp. 729-780). Mahwah, NJ: Lawrence Erlbaum Associates, Publishers.

Roth, W-M., & Barton, A. C. (2004). *Rethinking scientific literacy*. New York, NY: Routledge Falmer (Taylor and Francis Group).

Saldaña, J. (2016). *The coding manual for qualitative researchers* (3rd ed.). Thousand Oaks, CA: SAGE Publications, Inc.

Sangsa-ard, R., Thathong, K., & Chapoo, S. (2014). Examining grade 9 students' conceptions of the nature of science. *Procedia – Social and Behavioral Sciences, 116*, 382-388.

Scherz, Z., & Oren, M. (2006). How to change students' images of science and technology. *Science Education, 90*(6), 965-985.

Schwab, J. (1962). The teaching of science as inquiry. In J. Schwab & P. Brandwein (Eds.), *The teaching of science* (pp. 3-103). Cambridge, MA: Harvard University Press.

Schwartz, E., & Noam, G. (2016). *Informal Science Learning in Afterschool Settings: A Natural Fit? DRAFT*. Retrieved from: http://sites.nationalacademies.org/cs/groups/dbassesite/documents/webpage/dbasse_080087.pdf

Shah, A., & Noam, G. (2013). *Game changers and the assessment predicament in afterschool science*. Retrieved from www.afterschoolalliance.org/documents/STEM/Noam_Shah.pdf

She, H-C. (1998). Gender and grade level differences in Taiwan students' stereotypes of science and scientists. *Research in Science and Technological Education, 16*(2), 125-135.

Shernoff, D. (2010). Engagement in after-school programs as a predictor of social competence and academic performance. *American Journal of Community Psychology, 45*(3), 325-337.

Smith, C., Maclin, D., Houghton, C., & Hennessey, M. (2000). Sixth grade students' epistemologies of science: The impact of school science experience on epistemological development. *Cognition and Instructions, 18*(3), 349-422.

Stinner, A., & Williams, H. (1998). History and philosophy of science in the science curriculum. In B. Fraser & K. Tobin (Eds.), *The international handbook of science education* (pp. 1027-1045). Dordrecht, NL: Kluwer Academic Publishers.

Suncor Connections. (2015). Actua camps electrify youth imagination. Retrieved from http://connections.suncor.com/regional-municipality-wood-buffalo/october-2015/actua-camps-electrify-youth-imagination

Suter, L. (2016). Outside school time: an examination of science achievement and non-cognitive characteristics of 15-year olds in several countries. *International Journal of Science Education, 38*(4), 663-687. http://dix.doi.org/10.1080/09500693.2016.1147661

Tintori, A. (2017). The most common stereotypes about science and scientists: what scholars know. In Tintori,. & R. Palomba (Eds.), *Turn on the light on science*, (1–18.) London: Ubiquity Press. DOI: https://doi.org/10.5334/bba.b.

Tucker-Raymond, E., Varelas, M., Pappas, C., Korzah, J., & Wentland, A. (2007). "They probably aren't named Rachel": Young children's scientist identities as emergent multimodal narratives. *Cultural Studies of Science Education, 1*(3), 559-592.

Vandell, D., Reisner, E., & Pierce, K. (2007). *Outcomes linked to high-quality afterschool programs: Longitudinal findings from the Study of Promising Afterschool Programs*. Report to the Charles Stewart Mott Foundation. Retrieved from http://education.uci.edu/childcare/pdf/afterschool/PP%20Longitudinal%20Findings%20Final%20Report.pdf

Vygotsky, L. (1978). *Mind in society*. Cambridge, MA: Harvard University Press.

Woodland, M. (2008). Whatcha doin' after school? A review of the literature on the influence of after-school programs on young black males. *Urban Education*, *43*(5), 537-560.

Yin, R. (2014). *Case study research: Design and methods* (5th ed.). Thousand Oaks, CA: SAGE Publications.

Appendix A

UNIVERSITY OF MANITOBA | Research Ethics and Compliance

Human Ethics
208-194 Dafoe Road
Winnipeg, MB
Canada R3T 2N2
Phone +204-474-7122
Email: humanethics@umanitoba.ca

PROTOCOL APPROVAL

TO: **Andrea Misner** (Advisor: Barbara McMillan)
Principal Investigator

FROM: **Zana Lutfiyya, Chair**
Education/Nursing Research Ethics Board (ENREB)

Re: **Protocol #E2017:081 (HS21059)**
"Impact of the Global Space Balloon Challenge on High School Students' Attitudes to Science and Understanding of Science"

Effective: September 14, 2017 **Expiry:** September 14, 2018

Education/Nursing Research Ethics Board (ENREB) has reviewed and approved the above research. ENREB is constituted and operates in accordance with the current *Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans.*

This approval is subject to the following conditions:

1. Approval is granted only for the research and purposes described in the application.
2. Any modification to the research must be submitted to ENREB for approval before implementation.
3. Any deviations to the research or adverse events must be submitted to ENREB as soon as possible.
4. This approval is valid for one year only and a Renewal Request must be submitted and approved by the above expiry date.
5. A Study Closure form must be submitted to ENREB when the research is complete or terminated.
6. The University of Manitoba may request to review research documentation from this project to demonstrate compliance with this approved protocol and the University of Manitoba *Ethics of Research Involving Humans*.

Funded Protocols:

- **Please mail/e-mail a copy of this Approval, identifying the related UM Project Number, to the Research Grants Officer in ORS.**

Appendix B

UNIVERSITY OF MANITOBA | Research Ethics and Compliance

Human Ethics
208-194 Dafoe Road
Winnipeg, MB
Canada R3T 2N2
Phone +204-474-7122
Email: humanethics@umanitoba.ca

AMENDMENT APPROVAL

October 11, 2017

TO:	**Andrea Misner** Principal Investigator	**(Advisor: Barbara McMillan)**
FROM:	**Zana Lutfiyya, Chair** Education/Nursing Research Ethics Board (ENREB)	
Re:	**Protocol #E2017:081 (HS21059)** **"Impact of the Global Space Balloon Challenge on High School Students' Attitudes to Science and Understanding of Science"**	

Education/Nursing Research Ethics Board (ENREB) has reviewed and approved your Amendment Request received on **October 5, 2017** to the above-noted protocol. ENREB is constituted and operates in accordance with the current *Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans.*

This approval is subject to the following conditions:

1. Approval is given for this amendment only. Any further changes to the protocol must be reported to the Human Ethics Coordinator in advance of implementation.
2. Any deviations to the research or adverse events must be submitted to ENREB as soon as possible.
3. Amendment Approvals do not change the protocol expiry date. Please refer to the original Protocol Approval or subsequent Renewal Approvals for the protocol expiry date.

Appendix C

University of Manitoba | Faculty of Education

227 Education Building
University of Manitoba
Winnipeg, Manitoba
Canada R3T 2N2

LETTER OF INVITATION

November 10th, 2017

Dear [Student]

My name is Andrea Misner. You will remember me as one of your Maples Collegiate science teachers and/or as the teacher who spearheaded the Maples Collegiate Global Space Balloon Challenge. I am currently working on a Master of Education degree in the Faculty of Education at the University of Manitoba. As part of my Master's degree I am going to be conducting a research study to learn about the experiences of student members of the 2016 Maples Collegiate Science Club who participated in the Global Space Balloon Challenge (GSBC). The purpose of the study is to learn about students' experiences in the GSBC and to develop an understanding of the influence of these experiences on attitudes towards science as well as perceptions of how science is conducted. Such information may also help other teachers with the design and development of out-of-school-time STEM programs with similar aims.

As a member of the 2016 Maples Collegiate GSBC, you are invited to participate in this study. If you choose to accept this invitation, your participation will involve a one-on-one interview with me. The interview is focused on your involvement in the Science Club and the GSBC and will require approximately 45-60 minutes of your time on a date, hour and Winnipeg location of your choosing.

Your participation in the study is voluntary, and it provides minimal risk to you, meaning no more risk than what you might encounter in everyday life. You will be assigned a pseudonym, and after completion of the interview the data you have provided will be uploaded to a password protected hard drive that will be securely stored in my home office before being transcribed by me on a password protected laptop to which I have exclusive access. The interview transcription, in the form of a docx file, will also be saved to the external hard drive with the audio file. As the anonymized data is analyzed, it may be shared with my advisor, Dr. Barbara McMillan. After completion of the analysis and writing of the thesis, the collected data will be aggregated and summarized for publication in a journal and conference presentations. The thesis itself becomes a public document accessible through the University of Manitoba library system. Although excerpts from your interview may be used in the dissemination of the findings, this data remains anonymous and will remain confidential by removing unique personal features or identifiers.

At any time during the research process you are free to withdraw from the study without consequences by simply contacting me. All data related to you will immediately be removed and securely destroyed. Further, once the thesis has been successfully defended in the year 2018, you will have the opportunity to obtain a summary of the results as an e-mail attachment or via Canada Post.

This study has been approved by the Education/Nursing Research Ethics Board. To participant in this study, an informed consent form must be signed and submitted to me immediately before the interview gets underway. If you have any questions about this study and your participation please feel free to contact me by email at andrea.misner@7oaks.org.

If you have concerns of complaints about this project, you may contact me, my advisor Dr. Barbara McMillan at barbara.mcmillan@umanitoba.ca or the Human Ethics Coordinator at 201-474-7122 or by email at humanethics@umanitoba.ca.

Sincerely,

____

Andrea Misner

Appendix D

UNIVERSITY OF MANITOBA | Faculty of Education

227 Education Building

University of Manitoba

Winnipeg, Manitoba

Informed Consent Form for Participants

Research Project Title: Impact of the Global Space Balloon Challenge on High School Students Attitudes to Science and Understanding of Science

Principal Investigator: Andrea Misner

U of M e-mail: misnera@myumaniotba.ca

Work e-mail: andrea.misner@7oaks.org

Thesis Advisor: Dr. Barbara McMillian

Telephone: 204- 474-9036

U of M e-mail: barbara.mcmillan@umanitoba.ca

This consent form is provided to you to outline the purpose and nature of a study to be used to assess your experience in the 2015-2016 Maples Collegiate Science Club and the 2016 Global Space Balloon Challenge. This document formally requests your participation in the study and your written informed consent as a participant. **This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask** (contact information included above). **Please take time to read this carefully and to understand any accompanying information.**

Your name_______________________________ Date______________________________

I ______________________________ hereby give permission for to undertake in this research case study by the University of Manitoba

Appendix E: Interview Questions

There are two research questions that the proposed study has been designed to answer: How is participation in the Global Space Balloon Challenge impacting on high school students' attitude to science? How is participation in the Global Space Balloon Challenge impacting high school students' understanding of how science is conducted?

Below I have included the questions to be asked during the open-ended interviews with individual students who participated in the 2016 GSBC. In light of the two research questions guiding the study, the interview questions focus on attitude to science and how science is conducted. First, I aim to elicit each student's understanding of their experiences with, and knowledge of, four factors associated with attitudes towards science. These are family attitudes toward science, peer attitudes towards science, motivation in school science, and perceptions of herself/himself as a scientist. Second, my intention is to pose questions that will elicit students' experiences in school science, including the GSBC, and views on how science is conducted. The interview questions are not listed in the order in which they will be asked. Rather, they are arranged under the appropriate heading associated with the aforementioned contexts. Once the informed consent form has been read, discussed, and signed, permission will be requested for audio recording the interview. The first questions will focus on the student's recollection of his/her participation in the GSBC.

Open Interview Questions

Please note that many, if not all, of the interview questions provided here will include a follow up explanation or request for elaboration.

Let's begin with your past science classes. I'll give you a few minutes to think about the Science Club and the GSBC that you were part of in 2016. I'd like you to tell me about your experience.

Please note that many, if not all, of the interview questions provided here will include a follow up explanation or request for elaboration.

1. How did the GSBC club first come to your attention?
2. Tell me about your experiences in the GSBC club. - What things do you remember doing and learning in the GSBC club?
3. Describe the days leading up to the launch?
4. What challenges did you face in the club? – How did you over come them?
5. Describe the day of the launch.
6. What challenges did you face during the launch day? – How did you over come them?
7. Can you tell me about the benefits of joining the GSBC club?
8. Have you done anything like this project before hand?
9. How has these experiences impacted your views on how science is conducted?

Appendix F

UNIVERSITY OF MANITOBA

Faculty of Education

227 Education Building
University of Manitoba
Winnipeg, Manitoba
Canada R3T 2N2
Telephone (204) 474-9014

Pledge of Confidentiality

For Transcriber

Title of Research Project: Impact of the Global Space Balloon Challenge on High School Students' Attitudes to Science and Understanding of Science

Principal Investigator of the Research Project: Andrea Misner

I, ______________________ , understand that I will be transcribing audio recordings and reading transcriptions of confidential interviews. Research participants who participated in this project on good faith have revealed the information in the recorded interviews with the understanding that their interviews would remain strictly confidential.

I understand that I have a responsibility to honor this confidentiality agreement. I hereby agree not to share any information in the audio recordings with anyone except the principal investigator, Andrea Misner and her thesis advisor, Dr. Barbara McMillan.

Furthermore, I agree:

1. To hold in strictest confidence the identification of any individual(s) that may be revealed during the collection or handling of research data, or in any associated documents.

2. To store all research data and materials in a safe, secure location as long as they are in my possession.

3. To delete all electronic files containing data from my computer hard drive and any back-up devices after I no longer need this information as directed by the study principal investigator.

I am aware that I can be held legally responsible for any breach of this confidentiality agreement, and for any harm incurred to individuals if I violate this agreement.

Any violation of this agreement would constitute a serious breach of ethical standards, and I pledge not to do so.

____
Name of Transcriber (printed)

______ ____________
Transcriber (signature) Date

_________Andrea Misner ___________
Name of Principal Investigator (printed)

________ ____________
Name of Principal Investigator (signature) Date