THE CALLING OF AN ENGINEER: HIGH SCHOOL STUDENTS’ PERCEPTIONS OF ENGINEERING

by

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Abstract

The focus of this research study was to provide insight into high school students’ perceptions of engineering and the work engineers do. Participants included Grades 9 and 10 students, all of which were enrolled in academic English, Math, Science courses and are on the pathway towards college or university. This research was framed within a constructivist theoretical framework, and sequential multiple methods were utilized for data collection. The phase 1 questionnaire incorporated closed and open-ended questions pertaining to the engineering profession and was completed by 97 students, while 11 students participated in the phase 2 semi-structured interviews.

The findings show that the major categories that emerged from these students’ descriptions of engineering involve the mental aspects of designing or creating, knowledge in Math and Science, and the physical aspect of building. In addition, some students were very clear that designers are the source of creative and innovative ideas, scientists are the source of new theories, and engineers are responsible for turning those creative ideas and/or the new theories into reality by physically building something. The perception that engineering involves building was a major source of confusion as many of these students described engineers in roles that could also be used to describe skilled trades. Therefore, a significant percentage of these Grades 9 and 10 students have unclear views about engineering, which suggests they currently cannot make an informed decision in considering engineering for a possible career path.

An increase in student awareness of the engineering profession is needed to ensure students have the knowledge to make informed career choices, which may lead to achieving high-quality engineering graduates and diversifying the profession in Canada.
One way to meet the current demand for engineers within Canada may be to ensure that pre-university students have sufficient knowledge about the work of a professional engineer as well as the important aspects of the profession. With this knowledge, they can make an informed decision in considering engineering as a possible choice for post-secondary study.
Acknowledgements

Writing this thesis and the experience as a graduate student over the past two years has been challenging but would not have been as rewarding without the support of many individuals.

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Thank you to my professors in the Faculty of Education who provided me with the knowledge and professional development opportunities to practice qualitative research methods. I would also like to thank those in the Mechanical Engineering department and the school of graduate studies for being flexible and approving my request to enroll in graduate level education courses.

Thank you to Myriam Beaulne. Your help with scheduling and managing deadlines have been essential. In addition, your feedback and advice towards the final stages and revisions were much appreciated.

A special thanks is extended to the ‘engineering education community’ at Queen’s. To Allison Chong and Jake Armstrong, thank you for being with me along with journey as I learned a lot from both of you.

I am thankful for my supervisor, David Strong, and his passion ‘engineering education’. I am thankful that we met two years ago and you introduced me to a field of engineering that I was unaware of. I also thank you for your help and guidance throughout the journey, and your NSERC research funding for supporting me.
I would like to acknowledge the love and support from my friends and family that have encouraged me to continue following my passion for engineering and education. I thank you for being full of joy and by my side as I celebrate this accomplishment.

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Chapter 1

Introduction

In 2009, Engineers Canada reported that the Canadian Engineering Labor Market predictions for 2009-2018 indicated that there will be an increased demand for nearly all engineering disciplines [1]. The 2015 revised version of the study continued to highlight a large and growing need to replace retiring engineers as they exit the workforce over the next decade [2]. Additionally, the labour predictions for the supply of engineers for all fourteen disciplines recognized by Engineers Canada is higher than the predicted number of jobs through to 2025 [2]. Therefore, if the predicted supply is greater than the demand for engineers, the question should focus on whether prospective students who are considering applying to study engineering, graduate from an engineering post-secondary institution, and then stay in the profession.

According to a 2015 report by the Ontario Society of Professional Engineers (OSPE) entitled Crisis in Ontario’s Engineering Labour Market: Underemployment among Ontario’s Engineering-Degree Holders, it suggests there is a problem with the number of qualified engineers that are not working in the engineering profession [3]. Specifically, only 29.7% of individuals with engineering degrees work as engineers or engineering managers in Ontario. If the trend of less than 30% of qualified engineers are working within the field, than 30% of the predicted supply of engineers will not be able to meet the demand through 2025. Synthesizing Engineers Canada’s report on the Labour Market predictions through to 2025 and OSPE’s report on the underemployment of engineers in Ontario, increasing the number of students graduating from engineering programs might not be the solution to this problem, but instead focusing more on students
who choose to study engineering because they have an accurate perception of what engineers do and have made an informed decision to study engineering. Increasing the level of knowledge that students from kindergarten to Grade 12 (K-12) have about engineering may contribute to more accurate perception towards the profession.

Improving K-12 education in terms of knowledge and careers relating to Science, Technology, Engineering, and Mathematics (STEM) has been a major focus over the past two decades across the United States [4]. In 2002, the United States National Academy of Engineering (NAE) surveyed 177 organizations involved with increasing the general public’s (adults and K-12 students) understanding of engineering and revealed that they spend approximately $400 million dollars annually to improving their understanding [5].

In response to this movement and to try to measure the impact of the NAE’s efforts, several studies have been conducted to determine students’ and the general public’s factual knowledge, attitudes towards, and perceptions of engineering [5], [6], [7], [8], [9], [10]. Despite these efforts, the American public’s and students’ level of knowledge about what engineers actually do is still largely unknown [5]. Within Canada, few studies have been conducted to determine how the general public and/or students perceive the engineering profession. Therefore, it is important to explore the level of knowledge and perceptions that the Canadian K-12 students have towards engineering.

Being a high school student is challenging. Being a high school student while planning for future career paths is even more challenging. When high school students are applying to university, the pre-requisite courses and the minimum grade cut-off average required for specific university programs can potentially limit what programs they can apply to. For example, in 2015 at Queen’s University, a minimum of 86% was the cut-off
average (other than exceptional situations) for students who were accepted to study engineering. This average includes the four pre-requisite Grade 12 university level courses: English, Calculus and Vectors, Chemistry, Physics, plus one other university level Math or Science course. These five courses make for a challenging last year of high school if a student is considering to study engineering. If a student is unsure about applying to engineering or considered it as a late option, they might not have all of the required prerequisites.

1.1 Auto Biographical Signature

Before completing my engineering undergraduate degree, my perception of engineering strictly encompassed the subjects of Mathematics and Science. Although these are important tools to apply to the engineering design process, I realized that a professional engineer does more than answer mathematics and science questions based on theoretical knowledge. In my opinion, a professional engineer is a problem solver. Engineers will typically apply the skills obtained from educational and experiential learning to design several possible solutions to any one problem, and then make the best decision based on specific criteria. This design-based approach to problem solving and the “applied” aspect of science is what I believe engineering should be known for. With my inaccurate perception of engineering as a high school student, I completed all of the prerequisite courses and selected engineering as my undergraduate degree with the intention of becoming a professional engineer.

Throughout the first three years of my undergraduate engineering degree, the courses were heavily weighted on theoretical content. During this period, I struggled to find the internal motivation needed for success. The notion of engineering at this point
made the profession seem very unappealing. In my fourth year, my pessimistic view of engineering became optimistic once I enrolled in the engineering professional skills courses. I realized that engineering was more about applying the knowledge to solve complex, real-world, open-ended problems.

To this research, I bring the lens of a graduate engineer and educator with practical experience working in both fields. I began my academic journey as a chemical engineering student at Queen’s University. After obtaining my degree, I worked as a team leader for a chemical engineering consultant firm for two years. This practical work experience reiterated to me how important problem solving is to the engineering profession. In 2010, I returned to Queen’s university and obtained my Bachelor of Education degree. As a chemistry teacher, I found myself incorporating engineering into my lesson plans to create opportunities for students to work in teams to solve open-ended problems. The link between the chemistry concepts and the “applied” aspects of engineering came natural and it helped the students make connections to real-world applications. At this point, I realized that these students had minimal experience with regards to solving problems as most of their formal education revolved around obtaining the ‘right’ answer.

My new perception about the engineering profession and my teaching and engineering experiences made me question the perceptions that current high school students have about engineering. In order for students to make an informed decision about whether or not to pursue engineering, they need to have accurate information about the profession. I seek to gain a better understanding of this issue through my research.
1.2 Statement of the Problem

The Canadian Engineering Labor Market predictions for 2015-2025 indicates a large and growing need for engineers over the next decade to replace the number of retiring baby-boom generation engineers leaving the workforce [2]. The OSPE report indicates that only 29.7% of qualified engineers in Ontario actually work as engineers, which is possibly contributing to the potential shortage [3]. To meet the demand, future engineers must come through the K-12 education pipeline. With the projected demand for engineers in Canada exceeding the supply of engineers working within the profession (assuming the trend that only 30% of qualified engineers in Ontario continues), it is worth investigating the level of knowledge and perceptions that high school students have about the profession as they are the next generation to enter the work force. This knowledge might provide insight towards the supply of engineering graduates in Canada.

1.3 Purpose of the Study

The purpose of this study was to describe the knowledge and/or perceptions that Grades 9 and Grade 10 students have about engineering. This study did not attempt to determine how a students’ perceptions changed after participating in an engineering intervention activity. To understand these students’ perceptions of engineering, exploratory research questions were asked.

1.3.1 Research questions

It is not clear what knowledge Grades 9 and 10 students have of engineers and the work that they do. Therefore, this research was designed to provide insight on the following questions:
1. How do these students describe engineers and the engineering profession?
2. How do these students describe the work of professional engineers?
3. How do these students describe the relationship between engineers and designers?

1.4 Rationale

A recent research study by a Queen’s University Master’s student investigated Grade 7 students’ level of knowledge at two different schools in Canada and suggested that a substantial majority had little or no knowledge of engineers or the demand [2]. This research was a first glimpse into Canadian students’ perceptions and serves as a platform from which this research study stemmed from. The rationale for selecting Grades 9 and 10 high school students for this study was to start filling in a gap in the literature on students’ perceptions of engineering. Also, students in Grades 9 and 10 should be thinking about what senior level classes they need to complete as prerequisites for university or college. This can be a pivotal moment for shaping their career paths. Grades 9 and 10 students were also selected for this study as they have the cognitive ability to provide a rich description of their individual perceptions of engineering.

1.5 Significance of the Study

The findings from this exploratory study serves to inform the fields of engineering and education. This localized first pass look at high school students’ perceptions about engineering will hopefully inform the research community of the need for further evolution and extrapolation of this research. If a sufficient number and breadth of studies are done, they can cumulatively provide sufficient information to draw more generalized conclusions and recommendations that might lead to a more generalized rationale for possible
intervention. By identifying potential knowledge gaps and misperceptions that Canadian high school students have about engineering, these studies could be used to design interventions to increase students’ level of knowledge about the profession and help them make an informed choice when considering engineering as a career pathway.

1.6 Organization

As an engineer, the design process approach to solving problems is essential. For this reason, the design process shown in Figure 1 has been modified from an introduction to ‘Engineering Design and Practice’ course at Queen’s University for undergraduate engineering students. This design process has been embedded throughout this study to help answer the research questions. This first chapter includes all of the information from the ‘Ask’ component (the problem statement and the purpose of the study).

![Engineering Design Process Diagram]

Figure 1: Engineering Design Process

Chapter 2 will discuss the ‘Imagine’ component of the process by presenting background research related to students’ perceptions of engineering. Chapter 3 corresponds to the research design of this study and is the ‘Plan, Create, and Test’ component of the
design process. Finally, to ‘Evaluate and Improve’ the study design, Chapter 4 presents the evaluated results. Chapter 5 discusses the evaluated results while Chapter 6 and 7 offer conclusions, implications, and future recommendations for improvement.
Chapter 2
Literature Review

Generativity, as defined by Shulman, is the ability to build on the research of those who have come before us and therefore grants the work integrity and sophistication [11]. For this research to be useful and meaningful, it must build on and learn from prior research exploring students’ perceptions. This chapter, classified as the ‘Imagine’ component in the engineering design process (Figure 1) first defines the word ‘perception’ and what it means within the research context, followed by a look into how students form their perceptions. This section also provides a summary and analysis of previous research relating specifically to perceptions about engineering.

2.1 What is Perception

The concept of perception is a complex field with its definitions debatably being rooted in the fields of Philosophy and/or Psychology. This thesis will purposefully not discuss the complexity of this debate, but acknowledges that both have helped to define the concept. In this study, the word perception refers to people’s direct recognition or understanding of the world which is constructed from the information obtained by means of the senses.

2.2 Forming a Perception

Forming a perception about an object or a phenomena consists of four fundamental elements and follows a perceptual process. The fundamental elements used in this study were originally proposed by Jordaan and Jordaan [12] and are illustrated in Figure 2.
In this study, the ‘people experiencing the perception’ (the perceiver) are the Grades 9 and 10 students and the ‘something being perceived’ is the engineering profession. The multiple stimuli by the senses and the context for every individual person are contributing factors. This is why students’ perceptions about engineering were collected from students with various backgrounds. Knowing that these four elements make up the fundamentals of forming a perception, it is important to acknowledge them and find out more about how the perceptual process influences students’ perceptions.

Randolph and Blackburn [13] see the four-step perceptual process as following a pattern and conceptualize the perceptual process by means of a model shown in Figure 3.
The process begins by asking people [students] to use all of their senses to collect information about a certain phenomenon [the engineering profession]. Then, people select the information that they want to notice (explicitly and implicitly) due to a range of factors. The frame of reference filter is the initial phase for making meaning out of the collected information. It is where individual characteristics of each perceiver become dominant with past and present experiences (good and/or bad). The final phase is the assignment of the meaning to the perceived phenomena. The information about the fundamental elements of perceptions and the perceptual process of how people form perceptions has played a significant role in deciding on a theoretical framework for this study.

2.2.1 Theoretical framework

The number of researchers collecting information from students about their knowledge and beliefs about certain topics is continuing to increase, as does the range of theoretical frameworks supporting them. A constructivist framework was used in this study. According to Patton, the founding questions that drive social construction and constructivism are “How have the people in this setting constructed reality? What are their
reported perceptions, ‘truths’, explanations, beliefs, and world-view? And what are the consequences of their constructions for their behaviors and for those with whom they interact?” [14].

Piaget and Vygotsky are two of the most well-known constructivists and based on their theories, they suggest that people construct their own knowledge and interpret their own realities. Using a constructivist lens to view learning is therefore affected by the content and organization of individuals existing knowledge [15] [16]. In the context of this study, the participants have already constructed their views about engineering due to a variety of means and this study is simply reporting on those constructed perceptions.

2.3 Research on Perceptions of Engineering

The idea of collecting data from students’ thoughts about science has been studied for many years. One of the most significant original research studies was a qualitative study conducted by Mead and Metraux [17]. This study concluded that high school students described stereotypical scientists as wearing lab coats and glasses, surrounded by test tubes and flasks, and working in a laboratory. Building off the recommendations from this study, Chambers [18] designed the Draw-A-Scientist-Test (DAST), which is an adaptation from Goodenough’s psychological tool entitled Draw-A-Man-Test. The DAST was designed to determine at what age children first developed distinctive images of the scientist. This test concluded, in support of [17], that the stereotypic image of a scientist appeared among students at the grade school level. Due to the non-verbal nature of the test, two advantage are that it can be used at an earlier age than other attitude tests and is easy to administer. The limitation of the DAST is that it relies heavily on the interpretive side of analysis. Research on students’ perceptions of science and/or images of a scientist were popular in
STEM education until the early 2000s when research on engineering started to emerge. Prior to looking at the research on perceptions of engineering, it is important to review a literature definition of engineering, Engineers Canada’s description of engineering work, and the Canadian Engineering Accreditation Board’s graduate attributes.

2.3.1 Defining engineering

Engineering, as defined by Tom Brzustowski, P.Eng, past president of NSERC is “the professional activity of creating artifacts and systems to meet people's material needs, with design as the central creative process, scientific knowledge and economic considerations as its essential inputs, and public safety as its overriding responsibility.” [19]

This concise definition of engineering is currently used as an introduction and framework to the ‘Engineering Design and Practice’ courses at Queen’s University for undergraduate engineering students. In addition to this definition, the engineering students revisit Engineers Canada’s description of what professional engineers do. According to their description, engineers:

“Design products, processes and systems that protect the environment, and/or enhance the quality of life, health, safety and well-being of Canadians”. [20]

Together, these definitions highlight the importance of design and the service engineers provide to society. These definitions are at the core of the design courses for students studying to become engineers at Queen’s University and were used at the core of this thesis.
All accredited engineering programs across Canada have the expectation that students graduating from an engineering undergraduate program must be able to demonstrate the Canadian Engineering Accreditation Board (CEAB) graduate attributes (Table 1). These attributes could be used to help identify a knowledge gap between high school students’ perceptions and the recognized important attributes for graduating engineers.

Table 1: CEAB Graduate Attributes [21]

<table>
<thead>
<tr>
<th>Graduate Attribute</th>
<th>Brief Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) A knowledge base for engineering</td>
<td>Competency in math, science, engineering fundamentals</td>
</tr>
<tr>
<td>2) Problem Analysis</td>
<td>Knowledge and skills to identify, formulate, analyze, and solve complex engineering problems</td>
</tr>
<tr>
<td>3) Investigation</td>
<td>Experiments, analysis and data interpretation, synthesis of information to reach conclusions</td>
</tr>
<tr>
<td>4) Design</td>
<td>Solutions for complex open-ended problems that meet specific needs and considerations such as safety, standards, economic, environmental, cultural and societal</td>
</tr>
<tr>
<td>5) Use of engineering tools</td>
<td>Create, select, apply appropriate techniques and modern engineering tools with an understanding of limitations</td>
</tr>
<tr>
<td>6) Individual and team work</td>
<td>Work effectively as a member and leader in teams</td>
</tr>
<tr>
<td>7) Communication skills</td>
<td>Communicate engineering concepts within the profession and with society.</td>
</tr>
<tr>
<td>8) Professionalism</td>
<td>Understanding roles and responsibilities of an engineer in society</td>
</tr>
<tr>
<td>9) Impact of engineering on society and the environment</td>
<td>Ability to analyze social and environmental aspects of engineering activities</td>
</tr>
<tr>
<td>10) Ethics and equity</td>
<td>Apply professional ethics, accountability, and equity</td>
</tr>
<tr>
<td>11) Economic and project management</td>
<td>Incorporate economics and business practices including project, risk, and change management</td>
</tr>
<tr>
<td>12) Lifelong learning</td>
<td>Identify and address their own educational needs to maintain competence</td>
</tr>
</tbody>
</table>
Throughout the review of the research relating to students’ perceptions about engineering, the CEAB graduate attributes will be highlighted throughout this chapter in bold text. This will serve the purpose of making direct and easy links from the research to the important graduate attributes. This next section will summarize the research that have met the inclusion search criteria containing the words ‘perceptions of engineering’.

2.3.2 Viewpoints of engineering from the general public

Within the United States, there have been several organizations within the engineering community that have tried to improve the public’s level of knowledge about engineering. Despite these efforts, the American general public still have misconstrued perceptions about engineering [22] [23].

In 1998, the American Association of Engineering Societies (AAES) launched a follow-up study in partnership with Harris Interactive to gain a better understanding of how the general public view the engineering profession compared to other professions [22]. The survey results indicated that engineers had consistently less prestige than doctors, scientists, teachers, ministers, and policeman. This led the AAES to conduct further investigation. The follow-up study, Raising Public Awareness of Engineering, modified the initial data collection methods to include a survey and interviews while narrowing the scope to focus just on engineers, scientists, and technicians [22]. From the survey results, it was concluded that;

1) Engineers are builders, makers, designers, and planners (there is a strong positive correlation between the participant’s highest completed level of education and the likelihood that they do not associate engineers with builders);
2) Engineering involves the **process of design**, however, most people did not recognize the product or application of those designs such as new forms of energy or the development of a new drug; and

3) Engineers are credited with contributions to **economic growth**, **leadership**, and **national security**, but were not recognized as contributing to the public’s **quality of life** and the **environment**, for inclusiveness, and for **social concerns**.

The interview portion of the study concluded that a majority of participants felt that they were ‘not very’ or ‘not at all’ well informed about engineering. The fraction of those who self-identified as poorly informed, was somewhat higher among less educated people (high school certification or less). Also, women considered themselves much less informed than men [22]. The overall impression from this national study is that many adults within the American public were not well informed about the profession. To increase the level of knowledge about engineering, the NAE decided that a more effective and consistent message about the profession should be developed.

The NAE’s report entitled, *Changing the Conversation*, is the final report from the 18-month follow-up study to improve the message about engineering [23]. The data collection methods for the study included a quantitative/qualitative multiple methods approach. The quantitative online questionnaire was done in two phases. The initial sample of teens and adults collected data from 666 adults (including an over sample of 200 adults), and 568 teens, ages 14-17. The second phase was another over sample for African American and Hispanics which collected surveys from 1213 adults and 1101 from teens. The qualitative data focused on the students’ views about engineering and consisted of; 4 same-sex focus group triads for children aged 9-11, 8 focus group interviews (4 in each
age group of 12-15 and 16-19), and one focus group for parents who had children in the age range of 9-19.

The online questionnaire first asked students to name a ‘very good choice’ of career from a selection of six different professions (doctor, scientist, engineer, architect, teacher, and lawyer). When the participants were asked how well they understood what the six professions do on a day-to-day basis, adults and teens were most familiar with doctors and teachers. Engineering was much less understood, especially among teens who had engineer as the least understood profession. The last component looked at important factors when choosing a career and asked participants to rate their relative importance of seven factors (interesting work, availability of jobs in the field, works that makes a difference, challenging work, salary, recognition, and prestigious field). Adults and teens equally rated ‘interesting work’ as the most important consideration when choosing a career. Adults had ‘job availability’ as their second choice and teens had ‘making a difference’.

Another component of the questionnaire explored participants’ perceptions about engineers through an open-ended question. They were asked to describe the first words that came to mind when they hear the word engineering. They were also asked to select how well a list of 25 attributes describe engineering and/or engineers. The highest frequency of responses from the open-ended question for adults were the words ‘builders, buildings, and construction’ (22-30% of responses) while the highest frequency for teens was ‘math and science’ (21-31% of responses) [23]. One interesting point is the relationship between the informed [about engineering] adults and the non-informed, and the association to “math and science”. The informed adults were significantly more likely to make this link. Out of
the 25 attributes that describe engineering, the top three ranked (and percent of participants who selected each) for both adults and students are;

1. **Good at math/science** (86% and 84%)
2. **Designs, draws, and plans things** (61% and 63%)
3. **Problem solver** (59% and 62%) [23].

The focus groups and triads provided triangulation and validity to the questionnaire in that similar conclusions could be made. The supporting conclusions from the interviews were that most students understand that engineers ‘**design and build**’ things, they have a generally positive impression of engineers, and they think that engineers’ work is performed mostly on computers and involves little contact with other people. However, when students were asked about what engineers actually do, it appeared their knowledge was limited. Two other valuable pieces of information were that many students feel they are not smart enough to become engineers, and that most girls believe women can be engineers as well as men. However, when asked to name an engineer, most students could only name men.

The two NAE’s research studies provide insight into how the American general public view engineers and the engineering profession. The combination of using multiple methods to collect data for the *Changing the Conversation* report increased the trustworthiness of the results and strengthened the conclusions. From these reports, it can be concluded that the general public view the engineering profession in a positive light, and consider their work rewarding and important. The message about the importance of math and science (which many view as negative) is being heard. Most adults and teens had a poor idea of what engineers actually do day-to-day and there is a strong sense that
engineering is not for everyone (perhaps especially not for girls). To broaden the views about the engineering profession, further research focusing on students’ perceptions is necessary.

2.3.3 Viewpoints of engineering from elementary school students

Researchers at the Museum of Science in Boston were the first to use the Draw-An-Engineer-Test (DAET) which they modified from the DAST to allow students the opportunity to describe what they know about engineering. The advantage to giving students the freedom to draw what they think about engineering (as supported by previous versions of the drawing tests [18]) is that it provides another form of communication, other than just written. However, the disadvantage is that it requires a lot of interpretation of the drawings. With the DAET, another possible limitation is that the students are only drawing one image of an engineer (possibly even the stereotypical engineer) as opposed to the entirety of their knowledge.

The original DAET study provided students (Grades 3-12) fifteen minutes to complete both the written component and the drawing component to answer the research question of ‘What does an engineer do?’ [24]. The written component of the test had 384 participants (60 in Grades 3-5, 189 in Grades 6-8, and 135 in Grades 9-12) and the top four coded activities based on percentage of all responses were that engineers build (30%), fix (28%), create (17%) and design (12%). The drawing component had 253 participants (73 in Grades 3-5, 41 in Grade 6-8, and 139 in Grades 9-12) and the emerging themes were images of building/fixing (tools, hard hats, workbench, safety glasses, heavy machines), designing (desks, plans, blueprints, pens/pencils), mechanical products (bridges, roads, buildings, houses), trains, and images of lab work (test tubes) [24]. This inaugural study
is part of the foundation that further research built from to investigate student’s perceptions about engineering.

Continuing from their preliminary work with the DAET, researchers at the Museum of Science focused the scope of their research on students in Grades 1-5. Based on the conceptions students had previously indicated from the DAET about the work of engineers, they developed a list of 16 images and descriptions of people at work and asked students to circle the kind of work that engineers do [25]. The idea behind having students select all of the images they associate with engineering was to better assess the degree that students understand the range of engineering work. The limitation of this study was that the students could only choose from the pre-populated list of 16 images and were not provided the opportunity to offer anything else. However, the participants were also asked to answer the open-ended question “An engineer is someone who …” which did allow students to add their own thoughts about engineering.

This instrument was used in two different reports by the Museum of Science [25] [26]. The data collected in the first study came from a random sample of 504 students in grades 1-5 across 18 different schools within one district. The results indicated that over half of the students think engineers repair cars (78%), install wiring (75.2%), drive machines (70.7%), construct buildings (69.7%), set up factories (67.1%), and improve machines (63.5%). The open-ended responses added that students generally associate engineering with fixing, building, and vehicles [25]. The second study was conducted across 6 different states and collected data, pre and post the Engineering is Elementary (EiE) curriculum unit intervention [26]. The sample size of students (Grades 2-6) who underwent the EiE intervention was 5139 and the control group had 1827 participants. The
students who went through the EiE intervention had a much clearer understanding that the work engineers do involves design and teamwork. The EiE intervention students were less likely to select images such as ‘install wiring’, to associate with engineering.

Researchers at Purdue University have also been exploring elementary students’ perceptions of engineering. Researchers wanted to determine if students’ perceptions changed after spending a summer at the Gifted Education Resource Institute (GERI) completing an engineering outreach program [27] [28]. Using a constructivist approach for both the theoretical and methodological framework, Oware provided additional insight into students’ perceptions [8]. The criteria for participating in this study was that the students must have been enrolled in at least one GERI program (in actual fact, all participants were enrolled in two of the structural engineering courses). The data collection instruments used in this study consisted of the students’ initial application to the summer program, a pre/post questionnaire, a pre/post DAET, and individual pre/post semi-structured interviews. Unlike the previous research to determine elementary students’ perceptions of engineering that only used the DAET, the semi-structured interviews offered added triangulation. The six overarching categories and conclusions of how students describe engineers and the work they do at the end of this study were;

1) The physical work (building, constructing, repairing, fixing) or the mental work (designing, solving problems, planning) they do

2) The objects associated with engineering (infrastructure, vehicles, electrical/mechanical based, and computers)

3) The tools they use on construction sites (hammers, hard hats, and other physical labor tools) and in an office (desks)
4) Their professional characteristics (physical appearance, **solving problems**, working in teams, and content knowledge)

5) Images of engineers

6) Influences on students’ perceptions (family members [mainly fathers], personal experiences, and media)

Researchers at Purdue University continued to use a constructivist framework partnered with a multiple methods approach to further exploring elementary school students’ perceptions of engineering [29]. The DAET was conducted in 20 Grades 1-5 classrooms across one urban/inner-city community, one large suburban community, and contained 400 participants. Following the DAET, 80 interviews were conducted (4 per class and per grade). The four emergent themes were:

1) An engineer is a mechanic who fixes engines or drives cars/trucks

2) An engineer is a laborer who fixes, builds, or makes buildings, roads, or other structures

3) An engineer is a technician who fixes electronics and computers

4) An engineer is someone who **designs**

With the evolution of the Draw-An-Engineer-Test (DAET) [24], researchers have been able to use this instrument to explore how elementary students view the engineering profession. The various methodological approaches used in these studies (most use the DAET by itself or in combination with other data collection instruments) have contributed a significant amount of knowledge towards engineering education. The consistent themes that have emerged from these research studies are that engineers are a combination of **designers**, mechanics, technicians, and construction workers.
2.3.4 Viewpoints of engineering from middle school students

Researchers at the New Jersey Institute of Technology (NJIT) conducted a 6-point Likert scale survey of 1700 middle school students. The survey was designed to collect information on their attitudes towards Mathematics, Science, and engineering; knowledge about engineering and engineering career measures; who has spoken to them about engineering as a career option; and a measure of their recent academic performance [30]. All participants in the study had good grades (over 90%) and had some prior relationship to the NJIT in that they had either attended an outreach initiative, or their classroom teacher had completed a professional development program with NJIT. Results from the study indicate that 49% of the students identified that they know what engineers do, 61% agree that engineers make people’s lives better, and 56% indicate that having a job in science or math would be fun. When the participants were asked to list any 5 types of engineering, only 7% could do so, and 51% could not provide any correct answers or a response at all. Furthermore, when describing the work engineers do, 65% gave incorrect answers or no response. The final result from the survey indicated that 22% of participants mentioned that they have been spoken to by parents about the engineering profession [30]. Although 49% of students had indicated that they know what engineers do, when called upon to describe what they do, students lacked supporting evidence which indicates that they might not know as much about careers in engineering as they think.

The University of South Carolina (USC) participated in a graduate teaching fellowship program supported by the National Science Foundation (NSF) that partnered graduate students (called Engineering Fellows) with upper elementary and middle school STEM teachers. This partnership was designed to enhance daily science instruction and
provide engineering education intervention. In 2006, researchers wanted to determine the impact of the program by comparing data from 44 Grade 6 students who had completed the engineering fellowship program to a control group of 122 students who had not [31]. Data was collected in the form of a pre/post DAET with a supplemental story asking students to describe the action that was occurring, as well as follow-up interviews. The students who participated in the fellowship program were more inclined to describe engineers based on the mental processes such as designing and experimenting. The mental processes were supported by the drawings of the fellowship students as the artifacts were pertaining to computers, blueprints, models, making things better, and used the verbs fix, test, experiment, design, redesign, research, and invent to support the drawings. The control group focused rather on the physical work of engineers such as building and constructing. The drawings contained images of construction workers, auto repair technicians and operators and were supported with the verbs fix, build, make, drive and operate [31]. Conclusions from this study indicate that those students who had participated in the fellowship program had a better perception of what engineers do.

In 2008, USC reported on the evaluation of the graduate fellowship program and wanted to see the impact from both the DAST and the DAET [32]. This study was done with 4 cohorts of students and the data was collected over a six year period from students in Grades 6 – 8 who had attended one of eight area urban/suburban middle schools. This study contains 928 DAST and 744 DAET. For this study in particular, there was a limitation of using a checklist to evaluate the drawings as some of the richness of the information in the drawings may be hidden. The four emerging categories from the engineering component of the study were images relating to;
1. Species (most drawings contained a person), gender (50% male and 13% female), skin color (58.2% no identifiable skin color), and attributes (12.3% had laborer’s clothing).

2. Objects (vehicle at 19.8%, civil structure at 16.4%, and building tools at 16.3%)

3. Inferred action.
   I. Making/fixing/working with hands – 31.1%
   II. No action – 26.8%
   III. Operating/driving machines and vehicles – 11.3%
   IV. Designing/inventing/creating products – 10.1%
   V. Explaining/teaching – 2.2%
   VI. Experimenting/testing/creating knowledge – 1.9%
   VII. Observing – 1.8%

4. Location (50.9% no location, 32.1% outdoors, and 14.7% indoors)

   The conclusion from this study indicated that most students have inaccurate or lack of perceptions towards engineers. Specifically, they described engineers as “doers” or “worker bees”.

   In Canada, a study investigated perspectives of Grade 7 students towards engineering to see if Canadian students had comparable notions about the profession to previous research in America [33]. Collecting data from 61 open-ended surveys followed by 12 semi-structured interviews across two cities in two different provinces, this study provided a first glimpse into how Canadian students in Grade 7 perceive engineers. The results from this study are consistent with previous studies done with similar age groups across the United States. The students in general lacked a clear understanding of what an
engineer does and what is involved in the profession. When comparing the level of knowledge about engineering from those ‘who know an engineer’ to those who do not, there appeared to be no significant difference. There was also no significant differences between schools which were located in different provinces. The only difference of ‘knowing an engineer’ was that the students who did were modestly more likely to relate creativity and design with engineering and to believe that math and science are important.

A large majority of the students did not know what courses were required to study in high school if they wanted to become an engineer. Overall, this study suggested that Canadian students in Grade 7 also have misconstrued perceptions of the engineering profession.

At Queensland University in Australia, middle school students’ perceptions have also been studied. One study focused on Grade 7 students’ initial knowledge, awareness, and appreciation for engineering [34]. This longitudinal study was conducted with five middle school classes over a three-year period during which the entire classroom was video recorded and then analyzed to answer the research questions. The five main themes that emerged from the data are that engineers are involved with:

1. **Solving real-world problems**
2. Dealing with large construction
3. **Dealing with other fields**
4. **Designing**
5. **Helping the community**

The students also provided their opinion about what characteristics an engineer has, and what is required to become an engineer. The common themes were **cognitive functioning**, social and physical features, and **subject matter knowledge**. Consistent with
the literature thus far is that these students displayed a limited amount of knowledge about the various engineering fields, but recognized the importance of design. Some of the emerging themes from this study are different than those found in the literature discussed previously. These students recognized the importance of a range of cognitive abilities including creativity, future-oriented thinking, and imagination [34]. The fact that this study was conducted over three years as opposed to a one brief moment in time and was conducted in Australia, raises questions about how their education system compares to those of Canada and the United States.

2.3.5 Viewpoint of engineering from high school students

Similar to their work with elementary students, the NJIT reported on the attitudes of high school students towards engineering [35]. Using a 6-point Likert scale survey of 381 students who attended a career day at NJIT, researchers measured students’ views about engineering using the pre-developed ‘attitudes in engineering scale’, the ‘engineering self-efficacy scale’, the ‘self-confidence in academic subjects scale’, their academic history, and knowledge about engineering careers. Most of the students in the study seem to have a positive attitude towards engineering indicating that it could be an interesting career (86%) and that they were considering studying it (64%). However, 66% of students think that engineering wouldn’t be worth the effort and almost 50% indicated that they did not know if the advantages outweighed the disadvantages. From the engineering skills perspective, 80% realize that engineers require problem solving skills, 70% disagree that they are boring, and 50% disagree that they are nerdy. When asked about engineering disciplines and careers, only 25% could correctly name five different types of engineering and 30% gave no response or none were correct [35]. Overall, the students in
this study appeared to have a positive perception towards engineering but it might not be strong enough for them to consider engineering as a career path.

Washington State University reported secondary school students’ understanding of engineering [36] using conceptual ecology as their theoretical framework. Conceptual ecology draws upon constructivist learning theory and focuses on the interaction between individual concepts and how/why new concepts may fit within existing frameworks [36]. This study was conducted at a single rural high school of 500 students and 100 of them went through the engineering intervention where the researchers attended the school twice a month for two days at a time. Data was collected from 27 semi-structured interviews of which half of the students indicated that they were interested in an engineering career. Most students’ understanding of engineering could be defined in the three main themes of emphasis on **design** and building, difficulty differentiating engineering from **science and math**, and general uncertainty about the concept. In addition to these three main themes, a small portion of students also mentioned the emphasis on the **social services** of engineers and shared the complex view of engineering as a discipline of many facets. When using the conceptual framework to understand the results, the students do not appear to have a strong individual concept of engineering and rely on analogies to similar fields such as science, math, or construction when describing engineering.

### 2.4 Why This Study?

The future of engineering graduates who enter the profession in Canada is potentially dependent on the choices current high school students are making. Therefore, it is important to determine their level of knowledge about the profession and the perceptions they have towards careers in it. The research highlighted throughout this
chapter and summarized in Figure 4, shows that there have been several studies investigating elementary and middle school students’ views towards engineering. Very few studies have focused specifically on high school students’ perceptions of engineering, especially in Canada.

![Diagram showing perceptions of engineering across different educational levels.]

**Figure 4: Summary of Literature Findings**

From the studies that have been conducted to explore high school students’ perceptions about engineering, they appear to view careers in engineering in a positive light but have a general lack of knowledge and understanding about what engineers do. Therefore, research into how current high school students perceive the profession is an essential step.
Chapter 3

Research Design

The purpose of this research study was to determine the knowledge and/or perceptions that Grades 9 and Grade 10 students have about the engineering profession. As the demand for the next generation of engineers increases to replace those retiring, the supply of future engineers is dependent on current high school students. The few studies that have reported on high school students’ perceptions of engineering, suggest that students hold unclear views about the profession. These views may be a contributing factor for individual career choices and either lead students towards or away from engineering. The research design of this study was used to provide insight towards the following questions:

1. How do these students describe the engineering profession?
2. How do these students describe the work of professional engineers?
3. How do these students describe the relationship between engineers and designers?

The first part of this chapter outlines the study methodology and methodological framework, research setting, followed by participant recruitment and selection. The second part includes the method components used for data collection, and data analysis. Finally, a description of the approaches used to enhance the trustworthiness of the study are outlined.

3.1 Methodology - Multiple Methods

Qualitative research is a method of inquiry which seeks to interpret and understand social or cultural phenomena from the perspective of those participants, as individuals or
as groups, whom have experienced it [37]. To understand the perceptions that high school students have about the field of engineering, an exploratory approach is necessary. This approach will help to discover if significant themes, patterns, and categories emerge from the students’ responses as the participants. With few research studies in Canada focused specifically on the perceptions of engineering from the viewpoint of high school students, the topic warrants the need for ‘exploratory research’ [37, p. 139].

It is vitally important to know not only what students think about engineering, but the reasoning behind their thinking. This information would be best collected through a wide range or a combination of methods. As Patton describes, “just as machines that were originally created for separate functions such as printing, faxing, scanning, and copying have now been combined into a single integrated technology unit, so too methods that were originally created as distinct, stand-alone approaches can now be combined into more sophisticated and multifunctional designs” [37, p. 252]. Focusing on borrowing and combining distinct elements from pure methodological strategies and mixing the measurement, design, and analysis components of quantitative and qualitative inquiry strategies, a creative methodology specific to the research questions emerge (Figure 5). In this study, a naturalistic inquiry was used, which incorporated quantitative data collection methods (phase 1 questionnaire) and qualitative data collection methods (phase 2 interviews). To best answer the research questions in this study, a multiple methods approach was necessary as the analysis included a combination of content analysis and statistical analysis.
3.1.1 Methodological framework

The purpose of a methodological framework is to help guide the development of the research questions and the structure of the research methods. With the purpose of this study being to describe Grades 9 and 10 students’ views on engineering, a constructivist framework provides a solid platform to build from. Constructivism research design is based on the theory that people construct their own perceptions about reality as discussed in Chapter 2. For the purposes of this study, the constructivist framework supports asking the research questions in this study. The constructivist methodology impacted the data collection and analysis as an interpretivist approach was adopted to ‘understand and to portray the participants’ perceptions and understandings of the particular situation or event’ [38, p. 38]. This inductive approach allows for insights to emerge naturally through data
collection and analysis processes. In this study, the students’ descriptions of engineering served as the data collected to determine theses students’ perceptions.

3.2 Research Setting

This study was conducted at Queen’s University in Kingston, Ontario, Canada. The setting for this research study was spread across five high schools, all of which were from one school board as approval was granted to conduct the research in only one board. The schools were strategically selected based on their enrollment numbers, geographic location (urban or rural), and a range of socio-economic status (SES) catchment areas the schools are located in. The demographic mixture of students across the five school allows for a diverse cross-section sample of the student population.

3.3 Participants

Prior to undertaking this study and contacting any participants, ethical approval was obtained from the General Research Ethics Board (GREB) at Queen’s University followed by ethical clearance from the school board. To work with adolescents, parental/guardian consent is mandatory as well as full disclosure regarding student confidentiality and the right to withdrawal from the study at any point. These important pieces of information were included in the ethics package sent to both GREB and the school board, and were contained within the letter of information provided to each parent/guardian. Figure 6 illustrates the ethics approval process, while the clearance letters from GREB, the school board, and the letters of information and consent forms can be found in the Appendices.
3.3.1 Participant criteria

With the purpose of this study in mind, it was decided to narrow the scope to focus on those students who are enrolled in the academic stream and are currently on track to apply to university. According to Patton, selecting participants in this manner is “purposeful” [37, p. 40]. Therefore, a criterion-based sampling strategy was applied and the inclusion criteria was that all participants must be enrolled in Grade 9 or 10 ‘academic level’ Math, Science and English classes during the 2014-2015 academic year. In this context, ‘academic level’ courses refer to academic pathway within the Ontario curriculum and are pre-requisites for taking the university level courses in Grade 11 and 12. The justification for the criteria was to describe students’ perceptions who demonstrate the required academic capabilities for potentially applying to study engineering. By using a criterion-based sampling strategy for this study, it is unknown if the sample population is representative of the entire school and/or Kingston population. This distinction is important to acknowledge as the perceptions that Grades 9 and 10 students have about engineering might be different if the criteria for sampling was altered or non-existent.
3.3.2 Recruitment and selection process

Following approval from the school board, the recruitment process began as is illustrated in Figure 7.

**Figure 7: Recruitment Process**

The first step was to initiate contact with principals via telephone to see if they were interested in having their school participate in the study. Following the initial phone calls, a meeting with the five principals was arranged to discuss the research in person and provide them with a Letter of Information (LOI). If the study was approved by the principal, individual teachers who were responsible for teaching the academic level Math, Science, and English classes for Grades 9 and 10 students were contacted and sent a LOI detailing their potential involvement. Finally, all students who met the inclusion criteria were provided with a LOI and consent form for their parent/guardian to sign and return to their host teacher (Appendix B). After the final consent forms were returned, the contact information was obtained and the participants were sent an email reminder of the study’s
purpose, their right to withdrawal, and a link inviting them to complete the questionnaire. As part of the consent form for phase 1, parents/guardians had the option to select if they allowed their child to be contacted, if selected, to participate in the phase 2 interview.

On the questionnaire, the students had the option to self-select if they were interested in having a follow-up interview. All students who expressed interest for phase 2 were then cross-referenced with parental/guardian consent forms from phase 1. The final candidates were selected for the interviews stratified by grade, gender, geographical location, and intention to study engineering.

With respect to student confidentiality, it was outlined that the questionnaires would be completed online using a secure program provided by the university called FluidSurveys. The phase 1 questionnaire was sent to the student’s individual school email account. The reason behind this email choice was to ensure that students’ personal email addresses were not collected.

3.4 Data Collection

The multiple methods used for data collection in this study were the phase 1 questionnaire and the phase 2 interview. In this study, the terms phase 1 and 2 do not imply that the phase 1 results impacted the design of phase 2 (a mixed method approach), the terms simply refer to a sequential order.

3.4.1 Phase 1 questionnaire

Using an online questionnaire as a research instrument provided the ability to collect data from a large population. Unlike traditional quantitative questionnaires that are designed strategically using factor analysis tools, the questionnaire in this study was
designed to be primarily qualitative in nature. It was constructed from elements of previous exploratory research studies [5] [6] [7] [39] [40], with the addition of several questions designed to provide insight about students’ perceptions of designers. Since the majority of the questions in this questionnaire were used in previous studies, the construct strategies also apply to this study. The questionnaire was structured to incorporate both closed (quantitative) and open-ended (qualitative) questions, and is divided into four sections. Including open-ended questions creates an opportunity for the students to express themselves without the influence of pre-determined categories [37]. The order of the questions was also purposefully designed to allow students to answer the broad open-ended questions prior to the closed questions to minimize any possible imposed bias.

The first section of the questionnaire (six of the seventeen questions) contained demographic questions to gather information about participants’ age, gender, school, and their intentions about post-secondary education. This data was used for descriptive analyses and served as factors for comparison purposes.

The second section consisted of a blend of previously asked questions from a series of literature studies used to assess youth, students’ and adults’ perceptions of engineering [5] [6] [7] [39] [40]. More specifically, four of the seventeen questions used in the questionnaire were originally designed and incorporated in the NAE’s Changing the Conversation study [5]. However, the questions were modified to incorporate a four-point Likert scale, forcing a response selection (removing the option to select the neutral response) to measure their attitudes or beliefs about engineering. The rationale for the four-point Likert scale was to require the students to make a decision and to eliminate any possible misinterpretation of the neutral responses. Further, the question from Cunningham
and Lachapelle’s survey was modified to include descriptions of the images instead of the images themselves [6]. Including these five questions into the questionnaire was important as they have been used in studies throughout the United States and will provide insight into how students in Ontario answer the same questions. This strategy illustrates the notion of “generativity” mentioned at the start of Chapter 2.

The third section consisted of four exploratory questions specific to this research study and were designed to determine students’ understanding about designers and the relationship between engineers and designers.

The fourth and final section asked students to indicate whether they know any engineers and if so, describe how they know them. As mentioned earlier, the final question was for the participants to self-select themselves as potential interview candidates. The complete phase 1 questionnaire can be found in the Appendices.

3.4.2 Phase 2 interviews

To delve deeper into the preconceived notions that these high school students have about the engineering profession and obtain a rich understanding of their knowledge, interviewing the individual participants was an ideal instrument. The type of interview selected for this study was the interview guide approach, also referred to as a semi-structured open-ended interview. The questions were prepared in advance; but in the course of the interview, some flexibility was allowed to adjust the sequence of the questions and to add questions based on the context of the participants’ responses. This semi-structured conversational style format helped to create a safe and less intimidating environment for the participants so they could speak freely about their knowledge of engineering.
The interviews consisted of twelve questions that varied from exact questions from phase 1 (4 of 12), modified questions from phase 1 but related to similar topics (3 of 12), new questions that explored deeper into students’ perceptions of engineering (4 of 12), and reflecting a response from phase 1 (1 of 12). The choice to use exact and modified questions from the questionnaire provided the student with the opportunity to answer the same questions in complete sentences. It also provided the ability to explore several ideas from the questionnaire in the form of data triangulation. The interviews lasted approximately fifteen to twenty minutes in length, were held in an observable quiet location at the host high school from which the participants were from, and were audio recorded for transcription.

3.4.3 Pilot test class

The use of a pilot test class can increase the trustworthiness of this study as it provided the researcher with the opportunity to collect preliminary data, receive feedback from the pilot class students, and validate the data collection instrument. The pilot test class was a Grade 12 Data Management class from a local high school that consisted of 18 students. The main advantage of using this group of students as the pilot class was that the students were familiar with sampling techniques through early exposure in the Data Management course. With this exposure, they were able to offer specific details in regards to improving the instrument for readability and user ability. Also, since the questionnaire was personally introduced, administered, and then observed by the researcher, any misunderstandings or confusion were immediately documented. Finally, the pilot class helped gauge the time allotment to complete the online questionnaire.
3.4.4 Instrument validation and credibility

Open-ended questions are a useful style for data collection and can produce rich and valuable responses from the participants. Careful consideration of the wording in every question is essential prior to collecting data. Construct internal validity is used to ensure that the measure is actually assessing what it is intended to, and not other variables. Data validation offers the opportunity to refine the protocol and/or the clarity of the questions asked. Internal validity is one of the key criteria addressed by positivist researchers. In qualitative research, credibility is the equivalent concept [41].

To assess the credibility of the phase 1 questionnaire prior to distribution, a pilot test class of students examined the items and provided feedback about the wording of each question to ensure they were measuring the intention of the question. As mentioned earlier in this chapter, several of the questions included in this study, were adapted from previous studies [5] [6] [40]. By using questions from previous studies, it increases the credibility of this study as the previous questions had already been evaluated to measure the key construct. Therefore, the credibility of these previous studies will apply to this study.

3.5 Data Analysis

The sequential multiple method design of this study incorporated various data analysis tools to obtain an understanding of students’ perceptions of engineering. This next section contains the information about how the combination of statistical testing between factors and content analysis on students’ responses were combined to answer the research questions. It also includes how the data analysis has increased the trustworthiness of the study.
3.5.1 Statistical analysis

Descriptive statistics were used to summarize, organize, and reduce large numbers of observations [41]. The quantitative components within phase 1 incorporated a four-point Likert scale to document participant’ responses. These responses were exported from FluidSurveys into Microsoft Excel and then into a statistical data analysis program called Statistical Package for Social Sciences (SPSS) for analysis. Data analysis from the questionnaire consisted of descriptive statistics such as frequencies, mean scores, and percentages that were used to summarize the findings. To determine if significant differences existed between factors, t-tests, analysis of variance (ANOVA) tests, and chi-squared tests were conducted. It is important to note that although these tests are commonly used in positivistic research studies, the majority of the questions in this multiple methods study required an interpretivist approach. By using an interpretive approach for the open-ended questions from phase 1 and from phase 2, it follows that statistical generalizability is typically not the aim of the research. Rather the researcher aims to produce generalizability within the context of the study, with the onus on the reader to determine transferability to other contexts [42].

3.5.2 Content analysis

Patton identifies the first step of qualitative analysis as developing a manageable classification or coding scheme [37]. In this study, there were two major sources of qualitative data; the open-ended questions from the phase 1 questionnaire, and the responses from the phase 2 interviews. When analyzing the content data of students’ responses, an inductive approach was utilized in conjunction with the constant comparative method to allow themes to emerge. The inductive design strategy allows the important
analysis dimensions to emerge from the reoccurring patterns found in the study without presupposing what the important dimensions will be [37]. This inductive approach to qualitative data analysis was necessary to help answer the exploratory research questions and allow the students’ perceptions of engineering to naturally emerge.

NVivo is a computer software program that is commonly used in qualitative studies to help with data analysis and was used in this study. The first step was to perform open coding on all of the data and then group reoccurring or similar responses together and giving them a code. When assigning a code, it was carefully compared to the other responses that had the same code to ensure it was properly grouped into a category. The next step was to examine all categories to see if the coded responses fit within the properties of that category. If not, an additional category was created. Finally, all categories were holistically compared to see if any overlap or relationships existed. Following data coding, the results were synthesized in a thematic approach to inform the research questions and were supported by the analyzed codes and direct quotations from the participants.

3.5.3 Trustworthiness and triangulation

Trustworthiness in naturalist inquiry (according to Guba in 1981 [41]) includes’ credibility (in preference to internal validity); dependability (in preference to reliability); confirmability (in preference to objectivity), and transferability (in preference to external validity/generalizability). To increase the overall trustworthiness of this study, all four of these factors were considered and addressed when possible to the best of the researcher’s ability.

Increasing the credibility of this study has been previously discussed in this chapter. Increasing the dependability of a naturalistic study is similar to addressing the issue of
reliability in a positivist approach. Inter-rater reliability is a qualitative research tool used to increase the dependability and the trustworthiness of the coded data and expand on the analysis. For this study, an experienced second coder was provided with a selected sample of data from the questionnaire and asked to code the data. Their coded data was then compared to that of the researcher’s to ensure that similar categories emerged. According to Krippendorf [44], the coders must be in agreement at least seventy percent of the time, which is evidence that a theme has some external validity or transferability [45]. External validity in positivist work is concerned with the extent to which the findings from one study can be applied to other situations. Transferability is the naturalist equivalent and it is the responsibility of the researcher to provide enough contextual information about the work to enable the reader to make such a transfer [43]. The transferability of this study is discussed within Chapter 7.

Triangulation was also used to increase the trustworthiness of this study [37]. Data triangulation can simply be viewed as using different approaches in support of one-another, such as a questionnaire and an interview, to answer the same question. To incorporate data triangulation techniques, data was collected from questionnaires and interviews. The data from both instruments were analyzed separately, which allowed for categories and common themes to emerge and then be compared. Finally, a digital audio recorder was used during the interviews and provided a complete and accurate record of all raw interview data which was transcribed and used to provide direct quotes that increase the trustworthiness of the study.

In addition to data triangulation, methodological triangulation increased the trustworthiness of the study as a field log, a questionnaire and interviews were used. The
field log provided a chronological record of dates, time, places, people, and observational notes during the interviews. Patton provided two categories for triangulated reflexivity inquiry as self-reflexivity and reflexivity about those studied [37]. The self-reflexivity component was addressed by including an autobiographical signature at the beginning of this study that outlines the personal bias the researcher bring to this study. The reflexivity about those studied were answered by checking with the participants that the interpretations of the data are what they meant. By having a combination of data triangulation and methodological triangulation, the trustworthiness of this study was enhanced.

3.5.4 Presentation of quotations

The following chapters will include student quotations from phase 1 and phase 2. To help identify the participant, there will be a source code placed at the end of the quotation that will provide information about the students’ grade, gender, and school. The source code will be presented in the following format: [Student number_Grade_School_Gender]. In phase 2, instead of using the source code, a pseudonym name was used.
Chapter 4

Results

This chapter was organized by the sequential multiple methods approach used to describe the data collection methods discussed in Chapter 3. First, the quantitative and qualitative results from the phase 1 questionnaire provide initial insights into these students’ perceptions about engineering and what engineers do. Secondly, the semi-structured interview results in phase 2 provide a deeper understanding of those perceptions. Finally, the significant differences between the four factors are also presented.

4.1 Phase 1 - Description of Participants

The participants were recruited from 20 different classes across five schools ranging in size from 400 to 800 students in both urban and rural settings, including a range of socio-economic catchment areas within the academic year 2014-2015. By having a criterion-based sampling strategy, the number of potential participants at each school varied because of enrollment levels and school population. Out of a possible 862 students, a total of 124 students returned the phase 1 signed consent forms to participate in the study, a return rate of 14%.

Before the questionnaire was distributed, an email was sent to all participants thanking them in advance for participating in the study. It also reviewed the purpose of the study and reminded them of their right to withdrawal at any point without penalty. To increase the response rate, this email was sent to all participants two weeks prior to the questionnaire distribution which purposefully allowed time for any potential questions from participants. A total participant sample size of 97 students completed the online questionnaire, which is
a 78% completion rate. The demographic breakdown of students who completed the questionnaire is shown in Figure 8. From this figure, there was a 44% male and 56% female split between genders and the number of Grade 9 participants was much higher than Grade 10 participants (70 Grade 9 and 27 Grade 10).

![PHASE 1 - DEMOGRAPHIC BREAKDOWN](image)

**Figure 8: Demographic Breakdown (N=97 students)**

In addition to the grade and gender breakdown, the participants were also categorized by school. Figure 9 illustrates the total percentage of students from each school. For example, 26% of the students were from School A.

![PHASE 1 - SCHOOL BREAKDOWN](image)

**Figure 9: School Breakdown (N=97 students)**
The socio-economic status (SES) ranking between the five schools is based on the SES catchment area the school is located in and is shown in Table 2. The table also provides information about the location of the school and classifies it as either urban or rural.

Table 2: Relative SES Ranking and Classification of Schools

<table>
<thead>
<tr>
<th>School</th>
<th>SES Ranking</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1&lt;sup&gt;st&lt;/sup&gt;</td>
<td>Urban</td>
</tr>
<tr>
<td>B</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt;</td>
<td>Urban</td>
</tr>
<tr>
<td>C</td>
<td>3&lt;sup&gt;rd&lt;/sup&gt;</td>
<td>Urban</td>
</tr>
<tr>
<td>D</td>
<td>4&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Rural</td>
</tr>
<tr>
<td>E</td>
<td>5&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Urban</td>
</tr>
</tbody>
</table>

The participants were also grouped based on their relationship to an engineer. This information, illustrated in Figure 10, was the last factor analyzed to determine if significant differences existed among students’ perceptions.

Figure 10: Breakdown of Relationship to an Engineer

To determine if any of these factors had significant differences, a t-test was conducted to compare mean score differences between grades and genders as they were
comparing two variables. To determine if any differences existed between schools or relationship to an engineer, an analysis of variance (ANOVA) with a post-hoc test was run to compare mean scores since it involved more than two variables. When the results were in the form of a frequency count as oppose to the mean score, a Pearson Chi-Squared test was conducted to determine if any significant differences existed. Finally, when comparing all three statistical tests (t-test, ANOVA, and Pearson Chi-Squared), if the significance value indicated a statistical difference (p <= 0.1 and p <= 0.05), the mean values were highlighted along with the Cohen’s effect size.

4.2 Phase 1 – Students’ Intended Career Plans

As part of the introductory section of the questionnaire, the participants were asked about their current self-identified intentions for attending university or college, and their intentions towards studying engineering. This information was later used to help select the phase 2 interview participants to help provide additional insight into understanding these students’ perceptions of engineering. Using a four-point Likert scale with 1 representing ‘Definitely Not’ and 4 representing ‘Definitely’, the participants were asked to indicate if they are planning to attending university or college and if they are planning on studying engineering. The frequency breakdown and mean scores are shown in Table 3. From the results, the mean score for planning to attend university or college is very high at 3.79. The high mean score and frequency count of students who are definitely attending a post-secondary institution is as expected because of the criteria that was used within the recruitment process in that all participants are taking ‘academic level’ courses. The mean score for planning to study engineering at university or college is almost exactly in the middle of the four-point Likert scale. This score indicates that the average student is
somewhere between ‘Probably Not’ and ‘Probably’ going to study engineering. However, the frequency breakdown suggests that the majority of these students are probably not going to study engineering.

Table 3: Self-identified Post-Secondary Intentions

<table>
<thead>
<tr>
<th>Likert scale choice (with associated score)</th>
<th>Attending post-secondary (frequency count)</th>
<th>Studying engineering at post-secondary (frequency count)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definitely Not (1)</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>Probably Not (2)</td>
<td>1</td>
<td>52</td>
</tr>
<tr>
<td>Probably (3)</td>
<td>18</td>
<td>27</td>
</tr>
<tr>
<td>Definitely (4)</td>
<td>78</td>
<td>10</td>
</tr>
<tr>
<td>Mean score</td>
<td>3.79</td>
<td>2.40</td>
</tr>
<tr>
<td>Std. Dev</td>
<td>0.43</td>
<td>0.79</td>
</tr>
</tbody>
</table>

When analyzing the four factors to see if any differences existed for post-secondary intentions, the t-test and ANOVA were conducted on the means. The t-test results between these Grades 9 and 10 students did not indicate any significant differences. Male students have significantly higher interest in studying engineering at the post-secondary level than female students with a medium Cohen’s effect (p <= 0.05, d = 0.56) (Table 4).

Table 4: Gender Post-Secondary Intentions

<table>
<thead>
<tr>
<th>Likert scale choice (with associated score)</th>
<th>Studying engineering at post-secondary (frequency count)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Female (N=54)</td>
</tr>
<tr>
<td>Definitely Not (1)</td>
<td>4</td>
</tr>
<tr>
<td>Probably Not (2)</td>
<td>38</td>
</tr>
<tr>
<td>Probably (3)</td>
<td>9</td>
</tr>
<tr>
<td>Definitely (4)</td>
<td>3</td>
</tr>
<tr>
<td>Mean score</td>
<td>2.20</td>
</tr>
<tr>
<td>Std. Dev</td>
<td>0.66</td>
</tr>
</tbody>
</table>
The location of the schools had no significant difference on the students intentions for attending university or college, nor did it impact their intentions to possibly study engineering. Students who self-identified as having a personal connection to an engineer (20% of participants) were more likely to study engineering than those students who do not know an engineer with a medium Cohen’s effect size ($p \leq 0.1$, $d = 0.63$) (Table 5).

Table 5: Knowing an Engineer: Post-Secondary Intentions

<table>
<thead>
<tr>
<th>Likert scale choice (with associated score)</th>
<th>Studying engineering at post-secondary (frequency count)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No (N=43)</td>
</tr>
<tr>
<td>Definitely Not (1)</td>
<td>5</td>
</tr>
<tr>
<td>Probably Not (2)</td>
<td>26</td>
</tr>
<tr>
<td>Probably (3)</td>
<td>11</td>
</tr>
<tr>
<td>Definitely (4)</td>
<td>1</td>
</tr>
<tr>
<td>Mean score</td>
<td>2.19</td>
</tr>
<tr>
<td>Std. Dev</td>
<td>0.66</td>
</tr>
</tbody>
</table>

When starting to think about different career paths, there are several factors that students take into consideration, such as salary or job availability. The importance that students assign to these factors may influence their decision to eventually pursue or avoid certain careers. To better understand the potential factors influencing these students’ future career choices at this particular point in time, they were asked to select on a four-point Likert scale (1 = Not Important, 4 = Very Important) how important seven factors (interesting work, availability of jobs, work that makes a difference, challenging work, salary, recognition, and prestigious field) are for them when considering a career. The mean scores are displayed in Figure 11 and have been ranked in order from the highest considered
factor to the lowest. Interesting work was the most important factor while receiving recognition was the lowest.

![Figure 11: Factors Influencing Career Choices](image)

Comparing the influencing factors for each grade using a t-test, the significant differences between the mean scores indicate that the Grade 9 students are more concerned about a career that makes a difference \((p <= 0.1, d = 0.42)\) and significantly more concerned about a career within a prestigious field \((p <= 0.05, d = 0.45)\) compared to the Grade 10 students. The t-test analysis between genders and the ANOVA comparison between schools did not provide any statistical differences between groups. The students who had a family connection to an engineer were significantly more likely \((p <= 0.05, d = 0.70)\) to consider a challenging career over those who did not know an engineer.

### 4.3 Phase 1 - Knowledge of Professions

Understanding the level of students’ self-identified knowledge of different professions is a gateway to determining students’ perceptions of engineering. On the questionnaire, participants were asked to rate the level of knowledge they have about seven different professions (teacher, doctor, designer, lawyer, architect, scientist, and engineer)
and what they do on a day-to-day basis. The scale ranged from 1 to 10, with 1 representing ‘no knowledge’ and 10 representing ‘complete knowledge’.

In comparison to the other professions, the participants self-reported knowing the least about engineering (mean = 5.42 and std. deviation = 2.76) as illustrated in Table 6. Although students reported knowing the least about engineers, due to the large values for standard deviations across all professions, no statistical significant differences were found.

Table 6: Students’ Self-Identified Knowledge about Different Professions

<table>
<thead>
<tr>
<th>Profession</th>
<th>Mean</th>
<th>Std. Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher</td>
<td>7.45</td>
<td>2.12</td>
</tr>
<tr>
<td>Doctor</td>
<td>6.65</td>
<td>2.29</td>
</tr>
<tr>
<td>Designer</td>
<td>5.92</td>
<td>2.57</td>
</tr>
<tr>
<td>Lawyer</td>
<td>5.89</td>
<td>2.35</td>
</tr>
<tr>
<td>Architect</td>
<td>5.75</td>
<td>2.57</td>
</tr>
<tr>
<td>Scientist</td>
<td>5.71</td>
<td>2.48</td>
</tr>
<tr>
<td>Engineer</td>
<td>5.42</td>
<td>2.76</td>
</tr>
</tbody>
</table>

When comparing group differences for self-identified knowledge of the professions, no significant differences were found for grade or gender. However, the ANOVA results for school and knowing an engineer did indicate significant differences. Students at School A claimed to know more about the day-to-day work of a teacher compared to the students at School D (p <= 0.1, d = 0.82), and significantly more about an architect when compared to students at School E (p <= 0.05, d = 1.05). The students who identified they know an engineer had a significant impact on the level of knowledge about the engineering profession as the mean score for not knowing an engineer was significantly lower (p <= 0.05, d = 1.46 for no connection, d = 0.89 for personal connection, and d = 0.69 for family connection), no matter the relationship as shown in Figure 12.
The remainder of this chapter contains the results starting with the phase 1 questionnaire, followed by the phase 2 interviews. Within each phase, the presentation of the results will relate to the three research questions starting with how these students describe engineering, how they describe the work of a professional engineer, and finally, how they describe the relationship between designers and engineers.

4.4 Phase 1 - Describing Engineers and Engineering Attributes

To provide insight towards answering the research question of how do students describe engineers and the field of engineering, the participants were asked to 1) describe the first words, phrases, images that come to mind when they think about engineering; 2) select (using a Likert scale) how well a list of 24 descriptors describe engineers and/or engineering; and 3) what subjects are essential to take in high school to become an engineer.

4.4.1 Initial thoughts about engineering

Using the inductive analysis approach described earlier in this chapter, the codes that emerged are illustrated in Figure 13. The size of the word is directly proportional to
the frequency it was mentioned by these participants compared to the other words. For example, the word ‘design’ was the most frequent code mentioned by the participants and is the largest font size within Figure 13. However it does not indicate the overall frequency of the code as ‘design’ was only mentioned by 26 of the 97 students (27%).

Figure 13: Initial Codes to Describe Engineers and Engineering

The related codes that emerged from participants’ responses were then grouped together into seven categories. Figure 14 illustrates how three of the seven categories were developed using the codes that emerged from the student responses.
The categories used to describe engineering, although qualitative in nature, were also used for quantitative purposes. Figure 15 shows the total number of students (frequency) who provided a word that fit within the specific category.
The ‘Central Creative Process’ and ‘Essential Inputs and Skills’ categories were classified in an attempt to be consistent with the definition of engineering presented in Chapter 2 [19]. The ‘Central Creative Process’ (CCP) category was separated into mental components that included the words ‘design’, ‘create’, ‘innovate’, and physical components that included the word ‘build’. The mental category had the highest frequency of responses at 40 participants (41% of the total population), while the physical category had 25 participants. The ‘Skilled Trades’ category was the second highest frequency of responses at 38 participants and contains all of the codes that are used to traditionally describe skilled trades work such as ‘Construction/Tools’, ‘Mechanic/Machine’, ‘Pipes/Plumbing’, ‘Car/Engine’, ‘Electricity’, and ‘Fix Things’.

The depth and detail within students descriptions of engineering ranged from one single idea or word, to a sentence which encompassed multiple ideas. To provide information about the categories, qualitative examples of student responses within each category are provided in Table 7. As a reminder, the presentation of quotations represent [Student number_Grade_School_Gender].

<table>
<thead>
<tr>
<th>Category</th>
<th>Participant quote</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Creative Process (Mental)</td>
<td>“Learning how things work and being able to attach different ideas together to come up with either a new idea or a theory.” – [42_9_A_F]</td>
</tr>
<tr>
<td></td>
<td>“My robotics team, designing, innovating, working together as a team, designing the future” – [50 (Jenna from P2)_9_A_F]</td>
</tr>
<tr>
<td></td>
<td>“Working with science and math to innovate things, create, improve, discover.” – [64 (Rylan from P2)_10_A_M]</td>
</tr>
<tr>
<td>Skilled Trades</td>
<td>“Physical work, construction workers, helmets” – [30_10_C_F]</td>
</tr>
<tr>
<td></td>
<td>“Pipes - people running around fixing leaking pipes, operating switchboards” - [46_9_A_F]</td>
</tr>
<tr>
<td></td>
<td>“Hands dirty, Heating and cooling, Roads, Roofing” – [89_9_D_M]</td>
</tr>
</tbody>
</table>
A chi-squared test was used to compare the frequency of coded responses to identify if any significant differences existed among the four factors. The chi-squared results comparing grades and genders did not indicate any significant differences. When comparing schools and knowing an engineering, the chi-squared and post-hoc analysis indicated that the ‘Essential Inputs and Skills’ and ‘Professional Career Attributes’ categories contained differences (Table 8).
Table 8: Frequency Breakdown for School and Relationship with an Engineer when Describing Engineering

<table>
<thead>
<tr>
<th>Factor</th>
<th>Central Creative Process (Mental)</th>
<th>Skilled Trades</th>
<th>Essential Inputs and Skills</th>
<th>Central Creative Process (Physical)</th>
<th>Professional Career Attributes</th>
<th>Engineering Products</th>
<th>Uncertain</th>
</tr>
</thead>
<tbody>
<tr>
<td>School A</td>
<td>19</td>
<td>7</td>
<td>7</td>
<td>6</td>
<td>11**</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>School B</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>School C</td>
<td>19</td>
<td>11</td>
<td>13*</td>
<td>9</td>
<td>6</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>School D</td>
<td>10</td>
<td>11</td>
<td>6</td>
<td>6</td>
<td>1**</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>School E</td>
<td>4</td>
<td>7</td>
<td>0*</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>No</td>
<td>18</td>
<td>18</td>
<td>10*</td>
<td>15*</td>
<td>5*</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Yes – No connection</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Yes – Personal Connection</td>
<td>8</td>
<td>7</td>
<td>5</td>
<td>3</td>
<td>6</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Yes – Family Connection</td>
<td>11</td>
<td>10</td>
<td>14*</td>
<td>5*</td>
<td>10*</td>
<td>7</td>
<td>0</td>
</tr>
</tbody>
</table>

* Significant (chi-squared) for p <= 0.1  ** Significant p <= 0.05

Students at School C and students who had a family connection to an engineer were more likely (p <= 0.1) to mention the category ‘Essential Inputs and Skills’ (which contains the codes ‘Science/Technology/Math’, ‘Smart’, ‘Challenging’, and ‘Problem Solving’) compared to students at School E or those who did not know an engineer. ‘Professional Career Attributes’ is made up of the codes that mention that engineering has ‘multiple disciplines’, ‘helps people or the world’, is ‘fun or important’, and involves ‘working with people in teams’. Students at School A were significantly more likely (p <= 0.05) to mention these words when asked to describe engineering. Similar to ‘Essential Inputs and Skills’, the students who identified having a family connection to an engineer were more likely to use these words (p <= 0.1) when compared to the students who do not know an engineer.
Although the quantitative results have indicated differences (significant for professional career attributes) between the schools and for knowing an engineer, it is important to note that there was a range of student responses from all schools and all relationships with engineers. For example, a male student who is in Grade 9 at school D [87_9_D_M] who does not know an engineer says, “Well, when I think engineering I think of the branch of science and technology that is concerned with like the designing and building of machines, engines, and like structures. Or just being able to work artfully to sort of just bring something out.” Whereas another male student also in Grade 9 at school D [96_9_D_M] who does have a personal relationship with an engineer said that “hammer and nails” was the first thing that comes to mind and confirming the diverse range of responses within a factor. This demonstrates the breadth of responses from two male students who are in the same grade and school.

### 4.4.2 Attributes describing engineers or the engineering profession

To further investigate how the participants in this study view engineers and the field of engineering, the participants were asked to select, using a four-point Likert scale (1 = Not well at all and 4 = Very well), how well each attribute describes engineers or engineering. The frequency breakdown and the mean score for each attribute is presented in Table 9 and have been placed in order from highest mean score to lowest mean score for each attribute.
Table 9: Attributes Describing an Engineer

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Not well at all (1)</th>
<th>Not well (2)</th>
<th>Somewhat well (3)</th>
<th>Very well (4)</th>
<th>Mean Score</th>
<th>Stand. Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardworking</td>
<td>0</td>
<td>1</td>
<td>22</td>
<td>74</td>
<td>3.75</td>
<td>0.46</td>
</tr>
<tr>
<td>Good at Math and Science</td>
<td>0</td>
<td>7</td>
<td>26</td>
<td>64</td>
<td>3.59</td>
<td>0.63</td>
</tr>
<tr>
<td>Problem Solvers</td>
<td>0</td>
<td>3</td>
<td>36</td>
<td>58</td>
<td>3.57</td>
<td>0.56</td>
</tr>
<tr>
<td>Designs, draws, plans</td>
<td>1</td>
<td>2</td>
<td>43</td>
<td>51</td>
<td>3.48</td>
<td>0.60</td>
</tr>
<tr>
<td>Build, construct, make things</td>
<td>1</td>
<td>6</td>
<td>36</td>
<td>54</td>
<td>3.47</td>
<td>0.66</td>
</tr>
<tr>
<td>Gets results</td>
<td>0</td>
<td>3</td>
<td>46</td>
<td>48</td>
<td>3.46</td>
<td>0.56</td>
</tr>
<tr>
<td>Positive impact on lives</td>
<td>0</td>
<td>9</td>
<td>39</td>
<td>49</td>
<td>3.41</td>
<td>0.66</td>
</tr>
<tr>
<td>Inventors</td>
<td>0</td>
<td>12</td>
<td>33</td>
<td>52</td>
<td>3.41</td>
<td>0.70</td>
</tr>
<tr>
<td>Creative</td>
<td>0</td>
<td>8</td>
<td>42</td>
<td>47</td>
<td>3.40</td>
<td>0.64</td>
</tr>
<tr>
<td>Must be smart</td>
<td>1</td>
<td>13</td>
<td>40</td>
<td>43</td>
<td>3.29</td>
<td>0.74</td>
</tr>
<tr>
<td>Work is rewarding</td>
<td>2</td>
<td>5</td>
<td>55</td>
<td>35</td>
<td>3.27</td>
<td>0.65</td>
</tr>
<tr>
<td>Well paid</td>
<td>0</td>
<td>8</td>
<td>58</td>
<td>31</td>
<td>3.24</td>
<td>0.59</td>
</tr>
<tr>
<td>Original thinkers</td>
<td>0</td>
<td>11</td>
<td>58</td>
<td>28</td>
<td>3.18</td>
<td>0.61</td>
</tr>
<tr>
<td>Well respected</td>
<td>1</td>
<td>17</td>
<td>56</td>
<td>23</td>
<td>3.04</td>
<td>0.68</td>
</tr>
<tr>
<td>Leaders</td>
<td>3</td>
<td>23</td>
<td>45</td>
<td>26</td>
<td>2.97</td>
<td>0.80</td>
</tr>
<tr>
<td>Fun</td>
<td>3</td>
<td>21</td>
<td>56</td>
<td>17</td>
<td>2.90</td>
<td>0.71</td>
</tr>
<tr>
<td>Entrepreneurial</td>
<td>8</td>
<td>37</td>
<td>43</td>
<td>9</td>
<td>2.55</td>
<td>0.78</td>
</tr>
<tr>
<td>Often works outdoors</td>
<td>5</td>
<td>40</td>
<td>47</td>
<td>5</td>
<td>2.54</td>
<td>0.68</td>
</tr>
<tr>
<td>Nerdy</td>
<td>16</td>
<td>43</td>
<td>25</td>
<td>13</td>
<td>2.36</td>
<td>0.91</td>
</tr>
<tr>
<td>Requires too many years to get a degree</td>
<td>10</td>
<td>51</td>
<td>30</td>
<td>6</td>
<td>2.33</td>
<td>0.75</td>
</tr>
<tr>
<td>Mostly men</td>
<td>33</td>
<td>37</td>
<td>21</td>
<td>6</td>
<td>2.00</td>
<td>0.90</td>
</tr>
<tr>
<td>Sits at a desk all day</td>
<td>35</td>
<td>42</td>
<td>18</td>
<td>2</td>
<td>1.87</td>
<td>0.79</td>
</tr>
<tr>
<td>Boring</td>
<td>33</td>
<td>48</td>
<td>12</td>
<td>4</td>
<td>1.87</td>
<td>0.79</td>
</tr>
<tr>
<td>Mostly white people</td>
<td>44</td>
<td>40</td>
<td>10</td>
<td>3</td>
<td>1.71</td>
<td>0.78</td>
</tr>
</tbody>
</table>

The students in this study perceived engineers to be ‘hardworking’, ‘good at math and science’, ‘problem solvers’, and like to ‘design and make plans’. With the location being at the bottom of the list, the participants do not think that engineers are ‘nerdy’, that engineering consists ‘mostly of men’, or that engineering is ‘boring’.

Significant differences between grades were found for three attributes. Prior to presenting the differences, it is important to note that considering the relatively low number
of participants (n value), there is a high level of significance between the attributes. The Grade 9 students in this study were significantly more likely to say that engineers are entrepreneurial (p <= 0.05, d = 0.53) and more likely to say that engineering is fun (p <= 0.1, d = 0.35). The Grade 10 students however were significantly more likely to say that engineers are smart (p <= 0.05, d = 0.71). The t-test results from comparing genders indicated that there were differences in six different attributes, which are present in Figure 16. Overall, the female students were significantly more likely to associate engineers with the attributes ‘Builds, constructs, or makes things’ and ‘Inventors’ (p <= 0.05, d = 0.54 and d = 0.52) compared to the male students. They were also more likely to associate engineers with being ‘Leaders’ and ‘Nerdy’ (p <= 0.1, d = 0.35 and d = 0.40). The male students on the other hand were significantly more likely to associate the attributes of ‘Well paid’ and ‘Works outdoors’ to engineers (p <= 0.05, d = 0.41 and d = 0.50) than the female students.

Figure 16: Gender Differences for Engineering Attributes (*p <= 0.1 and ** p <= 0.05)
When comparing schools, a significant difference was found for only 1 attribute: problem-solvers. The participants at School A and School C associate the term problem solvers with engineers significantly more (p <= 0.05, d = 0.98 and d = 0.85) than the participants at School E. The problem solving attribute also had significant differences when comparing the students’ relationship with an engineer. The participants who did not know an engineer were significantly less likely to use ‘problem solvers’ to describe engineers (p <= 0.05, d = 0.90), or to describe engineering as ‘fun’ (p <= 0.05, d = 0.75) when compared to the participants who have a personal connection to engineers.

4.4.3 Essential high school courses to become an engineer

Participants were asked to identify which high school subjects are essential to take if they want to become an engineer. The participants had nine subject options to choose from (including an ‘other’ subject) and were asked to select all that apply. The percentage breakdown of students per subject is shown in Figure 17. Results from this question indicate that students have a strong belief that engineering involves Math and Science, and the third most important course is Technological Education. These participants have also indicated that English is the sixth most important high school course to study, after computers and business. The ‘Other’ category included six student responses who identified the specific courses of ‘Physics’ (two students), ‘Auto’, ‘Construction’, ‘Business Technology’, and ‘Integrated Technology’ as being important subjects.
The chi-squared test did not indicate any significant differences between Grade, Gender, or Knowing an Engineer but did indicate a difference between schools. The only subject that did have a significant difference was when comparing ‘Technological Education’ and the participants at School C and School D. Of the participants at School D, 95% indicated that ‘Technological Education’ was important which is significantly higher \((p < 0.05)\) than the 60% at School C.

The results from the three questions presented so far within this sub-section help to shed some light on how these students perceive engineers and the field of engineering. To understand more about their perception, it is important to determine how they describe the work of an engineer.
4.5 Phase 1 - Describing the Work of Professional Engineers

Participants were asked to 1) describe the first words, phrases, images that come to mind when you think about the work engineers do; and 2) select which job descriptions accurately describe the work engineers do.

4.5.1 Initial thoughts about the work of engineers

The reoccurring words that were used by the participants to describe the work of engineers are presented in Figure 18. Using the inductive coding procedure, the initial codes were then grouped into categories and the frequency of participants who mentioned each category are presented in Figure 19. As mentioned above, the size of the word represents the frequency of the word in relation to the other codes and does not indicate the total frequency of the code. For example, the code ‘design’ is the largest word within Figure 18 however it was only mentioned by only 27 participants (28%).

Figure 18: Codes Describing the Work of a Professional Engineer
The ‘Central Creative Process – Mental’ category had the highest frequency of responses at 41 participants, while the physical category had 28 participants. The ‘Skilled Trades’ category was the second highest category at 33 participants and contains all of the codes that are used traditionally to describe skilled trades work such as hard-hats, hammers, plumbing. The ‘Professional Career Attributes’ category from Figure 15 which included the codes ‘Helping People or the World’ and ‘Multiple Engineering Fields’ were left as single categories for this question as it was important to illustrate the number of participants in each code. Finally, the number of participants who indicated they were unsure about what an engineer does or indicated that nothing comes to mind suggests that some students are unable to provide specific examples of the work an engineer does.
Similar to the responses for describing engineering, the depth and detail of students’ descriptions about the work of a professional engineer ranged from one single idea to a complete sentence encompassing multiple ideas. Examples of student responses are provided in Table 10.

Table 10: Qualitative Responses Describing the Work of Engineers

<table>
<thead>
<tr>
<th>Category</th>
<th>Participant quote</th>
</tr>
</thead>
</table>
| Central Creative Process (Mental)     | • “I would say an engineer is responsible for making the design layout/blue prints of a structure or machine or engine, and then making it come to life. For example if they were making a structure they would have to figure out all of the variables like height width and just things that could affect its stability” – [87_9_D_M]  
                                           • “In my opinion a professional engineer would work to create new ideas about ways to solve problems in our everyday lives, or work on making those kinds of ideas a reality.” – [45_9_A_F] |
| Skilled Trades                        | • “There are many different areas of work that a professional engineer can do but one example involves work with machinery or equipment.” – [9_9_C_F]  
                                           • “they fix things ex: a car is broken so they fix it” – [19_9_C_F] |
| Central Creative Process (Physical)   | • "Build or make things for example cars” – [13_9_C_F]  
                                           • “I think a professional engineer would build stuff people always use. They would be part of building computers and vehicles” – [53_9_A_M] |
| Engineering Products                  | • “A professional engineer designs structures considering all the safety conditions and natural causes that could affect the structure. They design roads and bridges” – [2_9_B_F]  
                                           • “Computer Engineers basically help with all the programming for computers and the wifi.” – [69_9_E_M] |
| Helping People or the world           | • “Designs large things that make a difference in the world. For example, a bridge.” – [14_9_C_F]  
                                           • “They create products and create new items to help with the modern lifestyle” – [17_9_C_F] |
| Multiple Engineering Fields           | • “I know there are different types of engineering, like chemical engineering and mechanical engineering. But I don't know exactly what they all do” – [88_9_D_M] |
| Essential Inputs and Skills | “They build stuff by learning how things work and they use a lot of science and math” – [37_10_C_F]  
|                           | “In my opinion a professional engineer would work to create new ideas about ways to solve problems in our everyday lives, or work on making those kinds of ideas a reality.” – [45_9_A_F]  
| Uncertainty               | “I know that there are many different types of engineers, but I cannot point to specifics.” – [8_10_B_M]  
|                           | “I am not very well knowledge, but I am pretty sure that they put things together by using sciences and maths.” – [32_10_C_F]  
| Nothing comes to mind     | “I don’t really know” – [11_9_C_F]  
|                           | “I do not know.” – [27_9_C_M]  

The chi-squared results comparing the frequency of responses between grades indicate that Grade 10 students are significantly more likely to describe the work of an engineer using both the mental and physical components of the ‘Central Creative Process’ category as well as ‘Helping People of the World’ (p <= 0.05). Gender differences also existed as the female participants indicated they are unsure about the work of an engineer (p <= 0.1) when compared to the male participants. When comparing schools, the chi-squared and post-hoc analysis indicated that both the ‘Central Creative Process’ categories and the ‘Skilled Trades’ category contained differences. Students at School A were significantly more likely to mention the category ‘Central Creative Process’ compared to students at School E (p <= 0.05). The students in School A were also significantly less likely to describe the work of an engineer using the ‘Skilled Trades’ category compared to the students at School D and E. The final chi-squared analysis between knowing an
engineer indicated that the students who did not know an engineer were significant less likely to mention that there are multiple engineering fields than those students who have a personal connection to an engineer (p <= 0.05).

Many of the participants’ responses for describing the work of an engineer included a number of ideas that overlapped into multiple categories. For example, two students’ responses were coded into four different categories. A female student in Grade 10 at School A [59_10_A_F] says that the work an engineer does;

“depends on what kind of engineering they get into. Civil engineers deal with the design, construction, and maintenance of buildings, bridges, roads, etc. Chemical engineers manufacture essential products for our lives like medicine and make cool things like waterproof sprays and silicon chips that can hold a ton of data”.

Another female student at School A but in Grade 9 [50_9_A_F] said that the work is “depending on the type of engineer. For a chemical engineer they take raw materials and using chemical reactions and properties to make them into useful stuff. For a mechanical engineer they design and create lots of everyday buildings ”. These examples illustrate the high end within the range of students’ level of knowledge and possible perceptions about the work engineers do.

4.5.2 Job descriptions of a professional engineer

The previous open-ended question asked students to describe the work of an engineer in their own words. Even if students did not have the language to generate a response, this does not mean that students do not have any idea about the work that engineers do. Thus, a second related question format was used, asking students to select which job descriptions accurately describe the work of an engineer. Participants were
shown a list of sixteen job descriptions [6] and were asked to select ‘Yes’ or ‘No’ if each one describes the work of professional engineers. The total number of participants who said ‘Yes’ the job description matches what an engineer would do, along with the percentage of students who answered correctly for each description is presented below in Table 11. Within the list of job descriptions, six of the sixteen descriptions represent typical engineering activities. Although three of the other descriptions could arguably fall under an engineering job description (indicated by *), for the purpose of this study, they were not included as typical engineering activities.

Table 11: Percent of Correct Job Descriptions Describing the Work of Engineers

<table>
<thead>
<tr>
<th>Job description</th>
<th>Typical engineering activity?</th>
<th># of participants who said ‘Yes’</th>
<th>% Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Make pizza</td>
<td>No</td>
<td>1</td>
<td>99.0</td>
</tr>
<tr>
<td>Sell food</td>
<td>No</td>
<td>2</td>
<td>97.9</td>
</tr>
<tr>
<td>Clean teeth</td>
<td>No</td>
<td>2</td>
<td>97.9</td>
</tr>
<tr>
<td>Arrange flowers</td>
<td>No</td>
<td>3</td>
<td>96.9</td>
</tr>
<tr>
<td>Improves machines</td>
<td>Yes</td>
<td>96</td>
<td>95.6</td>
</tr>
<tr>
<td>Work as a team</td>
<td>Yes</td>
<td>93</td>
<td>92.8</td>
</tr>
<tr>
<td>Design things</td>
<td>Yes</td>
<td>91</td>
<td>90.7</td>
</tr>
<tr>
<td>Read about inventions</td>
<td>Yes</td>
<td>86</td>
<td>85.6</td>
</tr>
<tr>
<td>Design ways to clean water</td>
<td>Yes</td>
<td>77</td>
<td>77.3</td>
</tr>
<tr>
<td>Teach Children</td>
<td>No</td>
<td>27</td>
<td>73.2</td>
</tr>
<tr>
<td>Set up factories</td>
<td>Yes</td>
<td>64</td>
<td>63.9</td>
</tr>
<tr>
<td>Drive machines</td>
<td>No</td>
<td>53</td>
<td>47.4</td>
</tr>
<tr>
<td>Repair cars</td>
<td>No</td>
<td>64</td>
<td>36.1</td>
</tr>
<tr>
<td>Construct buildings</td>
<td>No*</td>
<td>65</td>
<td>35.1</td>
</tr>
<tr>
<td>Supervise construction</td>
<td>No*</td>
<td>66</td>
<td>34.0</td>
</tr>
<tr>
<td>Install wiring</td>
<td>No*</td>
<td>68</td>
<td>32.0</td>
</tr>
</tbody>
</table>

The four highest job descriptions were correctly identified by these students as not being typical engineering work were ‘make pizza’, ‘sell food’, ‘clean teeth’, and ‘arrange flowers’. The next three job descriptions correctly identified by the participants that
describe the work of an engineer are that they ‘improve machines’, ‘work as a team’, and ‘design things’. The job descriptions of ‘construct buildings’, ‘supervise construction’, and ‘install wiring’ have a low percentage of students who correctly identified that these do not describe the work of a typical engineer.

To measure if any significant differences existed between the four factors, the participants’ responses for each job description were scored as correct or incorrect. With these frequency counts for the number of correct answers, a chi-squared analysis could be performed. From the analysis, the Grade 10 students in this study were significantly more likely to correctly identifying that engineers ‘design things’ (p <= 0.05) and were more likely to correctly answer that engineers ‘design ways to clean water’ (p <= 0.1). The chi-squared results comparing genders indicated that the male participants were more likely to correctly identify that engineers do not ‘drive machines’ and ‘construct buildings’ than the female participants (p <= 0.1). In other terms, the female participants were more likely to believe that engineers do ‘drive machines’ and ‘construct buildings’, which is an incorrect job description of a typical professional engineer. The chi-squared and post-hoc analysis for comparing schools indicated that the participants at School A were more likely to correctly identify to engineers ‘design things’ and ‘design ways to clean water’ than the participants at School D (p <= 0.05). Finally, the relationship to an engineer did not have any significant differences for correctly identifying the sixteen job descriptions.

4.6 Phase 1 - Designers versus Engineers

Exploring the relationship between designers and engineers may provide another potential pathway towards answering the third research question in this study. To investigate how students perceive the relationship between a designer and the work of
engineers, they were asked to 1) describe the first words, phrases, and images that come to mind when you think about a designer and the work they do; and 2) identify the ways designers are similar and/or different to engineers.

4.6.1 Initial thoughts about designers and the work they do

The open-ended question of describing the first words or images that come to mind when thinking about a designer were coded using an inductive process and the emerging codes are presented in Figure 20. As a reminder, the size of the word is directly proportional to the frequency of the reoccurring code compared to the other codes. For example, ‘creative/create’ was the most frequently mentioned code and was stated by 23 of the 97 participants (24%).

![Image of Emerging Codes]

Figure 20: Emerging Codes Describing a Designer

The initial codes were grouped into categories and the frequency of participants who mentioned each category are presented in Figure 21. Seven of the nine categories that emerged when describing a designer were the same as the ones used to describe engineers. For the two new categories, ‘Visual Aesthetics’ contains the codes ‘Fashion/Clothing’,
‘Looks good’, and ‘Art or Artistic’ while the ‘Professional Careers’ category contains the codes ‘Link to Engineering’, ‘Skilled Trades’, and ‘Architect’.

Figure 21: Frequency of Categories Describing a Designer

The depth and detail within students descriptions of what comes to mind when they think about designers also ranged from one single idea or word to a complete sentence which encompassed multiple ideas. A sample of the qualitative responses within each category is provided in Table 12.

Table 12: Qualitative Responses Describing Designers

<table>
<thead>
<tr>
<th>Category</th>
<th>Participant quote</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Creative Process (Mental)</td>
<td>• “Creative, Innovative, Think outside the box.” – [58_10_A_F]</td>
</tr>
<tr>
<td></td>
<td>• “Basically they design stuff (what that stuff is depends on what kind of designing you so) using creativity” – [59_10_A_F]</td>
</tr>
</tbody>
</table>
**Visual Aesthetics**
- “Design things- clothes, and furniture” – [13_9_C_F]
- “A designer is someone who works on the way things look and how it can be useful to people. Maybe it would be making it a specific color because it would attract more people or a size that's more useful for someone.” – [42_9_A_F]

**Central Creative Process (Physical)**
- “A designer is someone who usually draws or sculpts and idea created.” – [2_9_B_F]
- “Drawing, pencils, sketches, sketchbook.” – [74_10_E_F]

**Engineering Products**
- “In my mind, designers work a lot with computers. Coding, graphic designing” – [1 (Miranda from P2_9_B_F]
- “I imagine someone who would help design a building or plan a design for roads/railways or other such things.” – [8_10_B_M]

**Professional Careers**
- “A designer creates things. An example of a job that requires designing would be architect.” – [3_9_B_F]
- “they are kind of an engineer in a way” – [29_9_C_M]

**Professional Attributes**
- “Strong” – [30_10_C_F]
- “Interesting, hardworking” – [78_9_D_F]

**Essential Inputs and Skills**
- “doing math at desk all day” – [25_9_C_M]
- “They problem solve and built machines. Or at least design machines”. – [37_10_C_F]

**Other**
- “Life saving” – [93_9_D_M]
- “Outdoors and Hydro” – [60_10_A_F]

**Nothing comes to mind**
- “No clue” – [88_9_D_M]

The chi-squared results when comparing the frequency of responses between grades indicate that Grade 10 students were significantly more likely to describe the work of a designer using the mental components of the ‘Central Creative Process’ (p <= 0.05). Gender differences also existed as four male participants indicated they did not know anything about what a designer does, which is significantly more than the female participants (p <= 0.05). When comparing schools and knowing an engineer, the chi-squared and post-hoc analysis indicated no significant differences.
4.6.2 Engineers versus designers

The open-ended question asking the participants to describe how engineers are similar and/or different to designers did not, in hindsight, clearly ask the participants to answer both questions. Therefore, the quantitative analysis for this question was not included in this study as the number of participants who described the similarities was different than those who described the differences. Fortunately, the qualitative analysis on the similarities and differences provides insight into how the participants relate these two professions. From the responses describing the similarities between engineers and designers, the emerging codes are presented in Figure 22.

![Figure 22: Similarities between Engineers and Designers](image)

The major similarity that emerged from the participants in this study is that both engineers and designers are creative and/or they create something. This is supported with an example from a male student in Grade 9 at school D who said that “They [designers] are similar to engineers because of the fact that they can both have a very creative and artistic mindset but also be able to counter in the variables in that math and science sort of way to get the results needed to succeed” [87_9_D_M]. The next two major similarities are that engineers and designers both have an element of ‘design’ in their jobs and they
normally design something to ‘help people’. “Designers and engineers are always coming up with new designs or concepts” [9_9_C_F]. Another student highlights how the work of both professionals involves helping people: “they both make things, they both invent, and build things, and design things that will eventually be relevant to the world we live in today” [18_9_C_F]. The final similarity is the notion that engineers and designers “both try to make things easier and/or better for others. They both have to work with technology and computers and aren't designers like, a type of engineers” [1 (Miranda from P2) _9_B_F].

The emerging codes to describe the differences between designers and engineers according to the responses are presented in Figure 23 and Figure 24. The major difference that emerged from the participants’ responses was that designers were responsible for creating or designing the plan and the engineers were responsible for building that plan.

![Create-the-plan](image)

Create-the-plan

Worry-about-aesthetics

Figure 23: What Designers Do That Engineers Don’t

![Build-the-Plan](image)

Build-the-Plan

Hands-on

Think-How/Why/It's-built Use Math-Science tech

Figure 24: What Engineers Do That Designers Don’t

One student described the differences between designers and engineers as “designers create the sculpture on paper or creates the models and the engineers build and construct the sculptures” [2_9_B_F] which is similar to another student who said that “well
from what I know, designers usually think of the plan and design, whereas engineers usually build those ideas” [71_9_E_M]. Another difference between the two professions was that the designers were more concerned about how something would look as opposed to the engineers who focus more on the technical components. Two students summarized this difference by saying that “They [designers] would also assist in the designing of buildings but they would focus more on aesthetic appeal and functionality then hard math and architectural ideas” [8_10_B_M] and “designers decide how something will look and be shaped and what it is supposed to do, engineers work out the technical aspects of it” [62_10_A_M]. The level of knowledge about the relationship between engineers and designers explored within this question provides additional insight into answering the research questions for this study of how these students perceive engineers, engineering, and designers. For some participants the differences between engineers and designers was unknown. “To be honest I have no idea because I have no background information on either of the professions” [78_9_D_F] is an example of the self-identified low level of knowledge about engineers or designers.

4.6.3 Phase 1 dependability

In addressing the issue of reliability from a positivist viewpoint, dependability is the equivalent naturalistic term. The phase 1 questionnaire incorporated several questions that provided opportunities to describe engineers and engineering work. To investigate the dependability of these students’ responses, the results from questions 9, 10, 11, and 16 can be analyzed.

Focusing on the concept of design throughout the questionnaire will provide insight into the dependability of these students’ responses. The open-ended responses from
question 9 indicated that 40 students mentioned words from the CCP category that included the word design to describe engineers. Of those 40 students, 27 of them (68%) used the same words to describe engineering work (question 10). In question 11, one of the descriptors that asked students to indicate how well it describes engineers or engineering work was ‘designs, draws, or plans things’. Of the 27 students who previously used the word design to describe engineers, 19 indicated that the descriptor above describes engineering ‘very well’ and the other 8 said ‘somewhat well’. Finally, on question 16 there were two job descriptions that contained the word design. All 27 students correctly identified that engineers ‘design things’, and 25 correctly identified that engineers ‘design ways to clean water’. The results from these four questions demonstrates the high level of dependability from students’ responses.

4.7 Phase 2 – Interview Participants

To build off of the phase 1 questionnaire results and develop a deeper understanding of these students’ perceptions about engineering, phase 2 interviews were conducted after the questionnaire. The rationale for the sequential multiple method design and conducting interviews after the questionnaire was to provide the participants with an opportunity to expand on some of their answers from phase 1, which served as a form of data triangulation. The interviews also provided the researcher an opportunity to explore deeper into several concepts related to engineering that either emerged from the phase 1 results, or had not previously been asked.

The interview selection process started by looking at the results from the phase 1 questionnaire in which the participants had the opportunity to self-select themselves as a potential interview candidate. Cross-referencing these students with the parental consent
forms from phase 1 that identified which students had consent to be contacted about an interview led to 48 potential candidates, all of which received another letter of information and consent form to participate in phase 2. A summary of the recruitment process and the potential number of students at each stage is shown in Figure 25. At the end of the process, a total of 22 potential interview candidates were available to select from.

Figure 25: Interview Selection Process

When selecting potential interview participants, the demographic information as well as the questionnaire responses from the 22 potential candidates were analyzed to determine which students would offer rich insight into students’ perceptions of engineering. The sampling strategy used to select the final interview participants was broken into two components. The first was to have at least one representative from each of the four factors (gender, grade, school, and knowing an engineer). The second component looked at the phase 1 questionnaire responses to see the potential candidate’s intentions towards studying engineering at university or college. In order to collect multiple
perspectives towards students’ perceptions, it was decided to have at least one representative from each of the four choices towards studying engineering (definitely not, probably not, probably, and definitely). At the end of the sampling strategy, a total of 11 participants; four Grade 9 females, three Grade 9 males, two Grade 10 females, and two Grade 10 males were invited to participate in an interview. The breakdown of each candidate and their pseudonyms are shown in Table 13.

Table 13: Interview Candidates

<table>
<thead>
<tr>
<th>Pseudonym</th>
<th>Grade</th>
<th>Gender</th>
<th>School</th>
<th>Know an engineer?</th>
<th>Attending university or college?</th>
<th>Studying Engineering?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jenna</td>
<td>9</td>
<td>Female</td>
<td>A</td>
<td>Personal</td>
<td>Definitely</td>
<td>Definitely</td>
</tr>
<tr>
<td>Miranda</td>
<td>9</td>
<td>Female</td>
<td>B</td>
<td>Family</td>
<td>Definitely</td>
<td>Probably Not</td>
</tr>
<tr>
<td>Ginny</td>
<td>9</td>
<td>Female</td>
<td>C</td>
<td>Family</td>
<td>Definitely</td>
<td>Probably Not</td>
</tr>
<tr>
<td>Tara</td>
<td>9</td>
<td>Female</td>
<td>D</td>
<td>No</td>
<td>Definitely</td>
<td>Definitely Not</td>
</tr>
<tr>
<td>Sean</td>
<td>9</td>
<td>Male</td>
<td>A</td>
<td>Personal</td>
<td>Definitely</td>
<td>Definitely</td>
</tr>
<tr>
<td>Jake</td>
<td>9</td>
<td>Male</td>
<td>C</td>
<td>No</td>
<td>Definitely</td>
<td>Probably</td>
</tr>
<tr>
<td>Conrad</td>
<td>9</td>
<td>Male</td>
<td>D</td>
<td>Yes - No description</td>
<td>Definitely</td>
<td>Definitely</td>
</tr>
<tr>
<td>Mica</td>
<td>10</td>
<td>Female</td>
<td>C</td>
<td>Personal</td>
<td>Definitely</td>
<td>Definitely</td>
</tr>
<tr>
<td>Rochelle</td>
<td>10</td>
<td>Female</td>
<td>E</td>
<td>No</td>
<td>Probably</td>
<td>Probably Not</td>
</tr>
<tr>
<td>Rylan</td>
<td>10</td>
<td>Male</td>
<td>A</td>
<td>No</td>
<td>Definitely</td>
<td>Definitely Not</td>
</tr>
<tr>
<td>Brad</td>
<td>10</td>
<td>Male</td>
<td>C</td>
<td>No</td>
<td>Definitely</td>
<td>Probably</td>
</tr>
</tbody>
</table>

The organization of the results from the phase 2 semi-structured interviews will first discuss responses to the research question of how do students describe engineers and the field of engineering. The second part will discuss the responses to the research question to describe the work of professional engineers, and then the relationship between engineers and designers. The third part of the interviews will highlight the students’ self-identified sources of perceptions and their exposure to engineering.
As discussed in Chapter 3, one form of data triangulation used in this study was to ask some of the same questions and topics from the phase 1 questionnaire, in the phase 2 interviews. The responses from the interviews are then used to clarify, confirm, and hopefully expand on the students’ prior responses.

4.8 Phase 2 - Describing Engineers and Engineering Attributes

To collect further information on how these students describe engineers and the field of engineering, the participants were asked in the interview to 1) describe the first words, phrases, images that come to mind when you think about engineering; 2) what characteristics are necessary in a person to become an engineer; 3) what factors or motivators would influence someone to pursue engineering; 4) what subjects are essential to take in high school to become an engineer; and 5) what are your initial thoughts after reading the literature definition of engineering.

4.8.1 First thoughts about engineering

Since this same question was asked in phase 1, a similar approach to analyzing and presenting the results is followed. The frequency of the emerging codes that describe engineers and engineering compared to each other are presented in Figure 26 but do not represent the total frequency count of each code. For example, the codes ‘build’ and ‘design’ were mentioned by 5 of the 11 interview participants (45%), and is why they are two of the largest words in Figure 26.
The emerging codes from within Figure 26 are consistent with those that emerged in phase 1 and therefore can be grouped into the same category names. By using the same category names from phase 1, it provides clear supporting examples to help triangulate the initial results as illustrated in Table 14.

Table 14: Phase 2 Responses for Describing Engineering

<table>
<thead>
<tr>
<th>Category</th>
<th>Participant quote</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Creative Process (Mental)</td>
<td>• “Inventing, innovation, and creating new stuff for the future” – Jenna</td>
</tr>
<tr>
<td></td>
<td>• “Engineers are mainly people who create.” – Rochelle</td>
</tr>
<tr>
<td></td>
<td>• “People who design stuff” – Brad</td>
</tr>
<tr>
<td>Skilled Trades</td>
<td>• “Protective head ware, gloves, and people who work construction” – Miranda</td>
</tr>
<tr>
<td></td>
<td>• “Anybody that works in a factory or does manual labor” – Tara</td>
</tr>
<tr>
<td></td>
<td>• “Working on cars” – Jake</td>
</tr>
<tr>
<td>Essential Inputs and Skills</td>
<td>• “Different forms of finding a solution for something” – Ginny</td>
</tr>
<tr>
<td></td>
<td>• “Figuring out the most efficient way to do something and have it work together” – Mica</td>
</tr>
<tr>
<td></td>
<td>• “Sciences and maths” – Rylan</td>
</tr>
<tr>
<td>Central Creative Process (Physical)</td>
<td>• “Building stuff” – Ginny</td>
</tr>
</tbody>
</table>
The mental aspect of the ‘Central Creative Process’ category was the major category that emerged from the phase 1 questionnaire and the phase 2 interview.

4.8.2 Characteristics to become an engineer

The students who were interviewed thought, that to become an engineer, it is important to be smart and knowledgeable. The characteristic that Tara describes as being “intelligent” emerged from all eleven interviews in some way. For instance, Sean also thought engineers are “smart [as they] have lots of degrees because a lot of it is science and things like that” while Jake supports the idea with his response by saying that engineers need to have “high English, academic math, sciences; knows what he is doing and has the skills that is takes. They also have to be creative and smart at their job”. This message is a consistent characteristic throughout this study.

Another consistent emerging theme throughout this study is that engineers need to be creative. This was mentioned by nine of the eleven students. For instance, Brad suggested that engineers have a “creative side to come up with designs.” Further, Rylan mentioned that engineers need to be “creative for sure to think of new ways to do things”, and Rochelle suggested that engineers need to be “able to think creatively and use a mix of left and right brain stuff”. Two other characteristics of engineers that emerged throughout
phase 1 and were supported by phase 2 are that engineers should enjoy working collaboratively in teams and solving problems.

An affective characteristic of engineers emerged from two students who discussed the idea that engineers have to be passionate about helping people or making a difference in the world. In addition to being creative and smart, Sean also mentioned that to become an engineer, you need to be “passionate about the subject you are working on, or care about other people because you are working to improve people’s lives”. Tara, who was the other student to mention this characteristic said that engineers “care about our world; want to make a difference; love creating new technology and establishing different ways of living; and generate new ideas throughout the community”. Although this characteristic was discussed briefly in phase 1, the responses of these two students illuminate the depth of some students’ understanding about engineering related to this characteristic.

A new characteristic that emerged from phase 2 that was not previously mentioned in phase 1, is that engineers should have an open mind, the ability to think outside the box, and have a willingness to try. Ginny (supported by Rochelle and Mica) best described the necessary characteristics for engineers as the ability to “think outside the box because you’re inventing new stuff; open to new ideas; anyone can be an engineer if they are open to new ideas and have a willingness to try and not afraid to fail”.

4.8.3 Motivators to pursue engineering

Asking the participants to identify the motivators or influences that someone might have to pursue engineering, several factors emerged. Typical to most motivators as to why someone would want to pursue any career, the participants expressed that a person must have an individual interest or passion for the subjects and/or field. Specifically for
engineering, Sean says that individuals likely have a “passion for sciences; like to make stuff; like to think of new ideas” which is supported by Miranda’s comment about “really like computers”; Tara’s “interest and passion for it”; Rochelle’s “interest of theirs”; and Jake’s “it depends on what they like”. These seven students suggest that the major influencing factor for pursuing engineering is personal interest.

Another possible reason why students might choose a career path is because of the financial security it brings. This motivator was apparent for the engineering profession as three of the participants discussed the idea. Rylan and Rochelle mention that for careers in engineering “I have heard the money is pretty good” whereas Conrad mentions the financial motivator but offers more insight into the reason why engineers might have high salaries. His response to the reasons why someone would choose engineering is “to be seen or make money. It’s probably a higher paying job because people’s lives can sometimes rely on your design”. The link between engineering careers and high salaries might be motivators for choosing the profession, however, the students’ rationale as to why it is high paying might need further exploration.

Similar to the emerging result that two students mentioned for describing a characteristic of an engineer as being passionate about helping people or making a difference in the world, five additional participants followed up and expanded on this as a motivator for pursuing the profession. Miranda suggests that a motivator for pursuing engineering to is “to improve the way people live; to make it easier for people to do certain things (ex. Easier to communicate or live their daily lives)” which is similar to Ginny’s reason of “trying to find ways to improve everyone’s lifestyle or to help other people, or to overall improve the world; or our outlook on the world”. These responses provide an
example of how some students make a connection between engineering and the service to society.

The last two motivators that emerged from the interviews were early exposure to engineering through school and extracurricular programs, as well as having intellectual freedom and independence. Jenna describes both of these factors in her response by saying;

“I think it is really fun if you have experience in high school or elementary school working with different stuff. I have done a lot of stuff outside of school with engineering and science stuff (experiments). You can be free in what you do, you can be creative and do what you want (flexibility). You don't need to follow someone else's thing.” [Jenna]

The motivating factor of exposure to engineering in schools is support by Mica as she said that her careers class does something to do with engineering and that gets you interested. However, it is the extracurricular factor being on the “robotics team [that] really helps to motivate”. This exposure to engineering in schools will continue to be explored later within this chapter.

4.8.4 Essential courses to become an engineer

By asking the interview participants what courses are essential to become an engineer, it provided them the opportunity to expand on the question in phase 1. The results from phase 1 indicated that 100% of students believe that Math is essential and 95% think Science is. These results are also consistent with the phase 2 interviews as every student discussed the importance of Math and Science. What the phase 2 interviews offer in addition to the phase 1 results is that the essential courses, as Ginny mentions are “depending on what type of engineering you are going into. Math and Science for the
majority of jobs. If you are working with computers, maybe business, tech, etc.” With the results from both phase 1 and phase 2 supporting the importance of Math and Science, it is Jenna’s response that really shows the breadth of essential courses.

“People think you always have to take math but that's not always the case; taking the sciences would help; maybe computer studies because technologies are getting more advanced and you're going to have to keep up; English because you have to type up lab reports, explain what you are making; a bit of freedom to choose courses depending on what type of engineering you are going into; having a wide range of courses.” [Jenna]

Her response not only mentions Math and Science, but highlights the importance of English and communication courses, computer technology courses, and the freedom to select other courses based on your interests within engineering.

The last essential courses that were mentioned by two interview participants were the arts and technologies. However, the depth of the art and technology subject was not expanded on. Rochelle said “arts and technologies [are essential] because it is kind of more hands on, but there’s also a lot of thinking that goes into it”. With Rochelle’s description, the technology category could still include multiple different subjects as discussed earlier in this chapter. Conrad on the other hand was specific about his opinion about the courses to become an engineer as he believes that “Tech; construction; math; sciences; and everything because you got to learn how to learn” are essential.

4.8.5 Reflecting on a literature definition of engineering

The final exploratory question to collect information about these students’ perceptions of engineers and the profession asked them to read the literature definition of
engineering described in Chapter 2 and then describe their thoughts about it. As a reminder, Engineering, as defined by Tom Brzustowski is,

“the professional activity of creating artifacts and systems to meet people's material needs, with design as the central creative process, scientific knowledge and economic considerations as its essential inputs, and public safety as its overriding responsibility” [19].

The initial reaction after reading this definition from most participants was that it was a “smarter way of saying what I said” [Miranda] and “it seems pretty accurate because it includes all of the aspects that I think you need to be an engineer. So you need economic considerations and creation, creative process and building things to meet people’s material needs” [Rylan]. Reusing the language from the definition was a common response as most students agreed with the definition and repeated the words. Tara offered her initial reaction by saying “I have never really heard the definition of engineering. But now that I think about it, I can pull all of my thoughts together and definitely know what engineering is”. Her response to seeing a definition of engineering for the first time in her life might provide a valuable piece of information in understanding students’ perceptions about engineering. Only one participant, Jenna, was apprehensive with the literature definition by saying “I feel it’s really. I don’t know how to describe it. I see the connection between like that they are trying to explain, but I feel like something is missing and I can’t pin point what it is”. Although she felt that something was missing from this definition, she was unable to offer her thoughts about what was missing.

To probe deeper into these students’ thoughts about the definition of engineering, they were asked to describe if anything was surprising, they didn’t know, or was missing
from the definition. The three themes that emerged from the follow up questions that were new or unknown to the participants were the specific components relating to the central creative process, economic considerations, and public safety. After reading the definition and asked if anything was surprising, Ginny responded with “maybe the creativeness. I didn’t think that to do this you would have to have some sort of creative process but it does make sense if you’re looking for the different, um, answers and solutions to problems.” In addition to creativity being a surprise to two participants, four were also surprised to read or “didn’t know about the economic consideration” [Brad] within engineering which is supported in Rylan’s response “I didn’t always consider the economic considerations thing. I forgot that, you know, they do try and build and create within the means, especially the economic means”. Finally, four interviewees mentioned that “one thing I hadn’t really thought about was public safety and its overriding responsibility. It’s like making sure that anything you bring out is safe and stuff like that. That didn’t really come to mind” [Sean]. After reading the definition and mentioning that public safety was something she never really thought about in relation to engineering, Tara offered “but now that I do think about it in that way, it is a very big role in engineering”. When reflecting on the components of this engineering definition, there is at least one part of it that the participants didn’t know. While this broad definition is currently being used at Queen’s University to help describe engineering to undergraduate engineering students, there are a few components of it that the high school students in this study are not aware of.

4.9 Phase 2 – Describing the Work of a Professional Engineer

To collect further information on how these students describe the work of a professional engineer the participants were asked in the interview to 1) describe the first
words, phrases, images that come to mind when you think about the work of an engineering; and 2) what are your initial thoughts after reading Engineers Canada’s definition of engineering work.

4.9.1 First thoughts about the work of a professional engineer

The emerging codes that describe the work of professional engineers are presented in Figure 27.

![Figure 27: Emerging Codes that Describe Designers from Phase 2 Interviews](image)

The emerging codes are relatively consistent from those that emerged in phase 1 except for the ‘nothing comes to mind’ category and have been grouped into the same category names to help triangulate the initial results as illustrated in Table 15.

<table>
<thead>
<tr>
<th>Category</th>
<th>Participant quote</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Creative Process (Mental)</td>
<td>“They would be in a lab with lots of resources so they can try to design technologies or things that make life more efficient or faster - things that would help people out daily; try to improve on things they already have - work to get a better solution or a cheaper way to make it” – Sean</td>
</tr>
<tr>
<td>Skilled Trades</td>
<td>“Some work almost in architecture I think, building buildings and stuff; some work with making different cars, different mechanics” – Rylan</td>
</tr>
<tr>
<td>--------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Central Creative Process (Physical)</td>
<td>“Find out the best way to build or design something; find out how it can withstand stuff (ex. CN tower. Trying to build it so it can sway side to side without cracking). – Conrad</td>
</tr>
<tr>
<td>Engineering Products</td>
<td>&quot;design anything that's sort of helpful, like computers, networks, websites, trains, transportation” – Miranda</td>
</tr>
<tr>
<td>Helping People or the world</td>
<td>“Design and build things that work help people in today's society; they work on something - they have an idea, plan it out and then test it, if that works then they build whatever it is they're planning” – Miranda</td>
</tr>
<tr>
<td>Multiple Engineering Fields</td>
<td>“It depends on the type of engineer; chemical engineers work with chemicals to make a prototype from small scale into large scale. They make anything from laundry detergent to care fuels; civil and mechanical engineer build bridges and buildings; electrical work with electrical stuff; programming you're programming stuff from cars, to robots, to simple machines.” – Jenna</td>
</tr>
<tr>
<td>Essential Inputs and Skills</td>
<td>“Use scientific stuff” – Jake</td>
</tr>
<tr>
<td>Uncertainty</td>
<td>“A film maker can be an engineer, or an artist can be an engineer; it's creative but also very academic” – Rochelle</td>
</tr>
</tbody>
</table>

Eight of the eleven students either started their response with a statement to the effect that the work an engineer does depends on the type of engineer they are. Jenna’s statement within Table 15 is one example of the breadth of knowledge that some students have about engineering disciplines. Mica also supports this statement with

“[it] depends on what area of engineering they do. A chemical engineer is going to do different things from a biomedical engineer (ex. a biomedical engineer maybe working on things like prosthetics for amputees). There are a whole bunch of different types of engineering, it’s everywhere”.

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With statements describing the work of an engineer that Mica and Jenna offer, it may indicate that some students are aware that different disciplines exist within engineering.

4.9.2 Reflecting on a literature definition of what engineers do

The final exploratory question to learn more specifically about these students’ perceptions of the work a professional engineering does asked them to read the literature definition by Engineers Canada and provide their reflective thoughts. The definition, offered by Engineers Canada says that engineers;

“Design products, processes and systems that protect the environment, and/or enhance the quality of life, health, safety and well-being of Canadians.” [20]

This definition describing the work of an engineer was held in high regard by the participants as five different participants mentioned that it aligns with their original thoughts about what engineers do. Tara was clearly much more supportive of this definition compared to the previous literature definition describing engineering by saying;

“I like this one a lot more. Even though they are two different questions, I feel like this is a definition that I would, umm, describe an engineer as if I was to put it in a professional term. This, to me, wraps up what an engineer does and definitely protecting the environment is what I think of an engineer. So having that in there makes me feel happy.” [Tara]

Jenna also supported this definition by saying;

“I like this one better than the one before because this one, it makes it more clear what engineers do and like, um, they specify, um, the products they do like protecting the environment, enhancing the quality of life and health safety. I think
that’s important for people to know. Oh the stuff engineers do are actually helping the world and us in a way.” [Jenna]

One student, Miranda, appeared to struggle with accepting this definition. Within her response she describes her initial thoughts about what an engineer does, identifies a possible source for her information, and then has difficulty finishing her train of thought. When asked to describe her initial reaction after reading the definition that describes the work a professional engineers does, she responded with;

“It sounds, it’s not what we learned in school. I guess I always thought that engineers, like before I talked to my dad, I thought that engineers were like construction workers that just build stuff but this makes a bit more sense. They like, they’re in charge of, well not in charge but, they are good at what they do and they, have a good, um, purpose to their jobs.”[Miranda]

Although the general first impression was positive about this definition and the students felt that it was a better representation of their thoughts about what engineers do, there were still a few components that were surprising, unexpected, or that they didn’t know. The three major themes that emerged from this definition that were surprising to the participants were 1) engineers have a role to play when protecting the environment; 2) they enhance the quality of life for people; and 3) engineers can manage world-leading companies. The first two themes relate to the idea that engineers ‘help people’, which was a category that emerged previously in this study. From Rylan’s perspective, he was aware that engineers were involved with protecting the environment but was surprised to see it within the definition and it may have caused him to question the link between engineering and the environment. “I mean the fact that they specified the protection of the environment that
sort of jumped out at me a little bit. I thought they would just leave it as a generalization but they went into specifics. So, maybe that’s one of the bigger parts of engineering” [Rylan]. The idea that engineering enhances the quality of life was at first a surprise to Brad but during his response, he made the connection between his own perception of engineering work and how it may enhance people’s lives. He offers, “I didn’t know they [engineers] would enhance the quality of life. Like, I thought they would just like, umm, design products so that it would just help you. Oh ya, that kind of does.” Tara agrees with Brad that the focus on enhancing the quality of life was a surprise to her. After making this claim, she returns to her original positive reaction to the definition by adding;

“I really do believe that everything in here wraps up what an engineer does and there are so many more qualities of an engineer that could be put in here. They definitely contribute a massive part to our economy. Umm, engineers are, I would call them, the base of the community because they are the ones inventing products that can help us sustain ourselves.” [Tara]

The final component that was surprising or that the students didn’t know was that engineers can manage world-leading companies. Depending on the students’ perception of the profession, it might be challenging to grasp this possibility. For Mica, she explains “I’ll admit that in part with the last phrase, the managing world leading companies, I can understand that but at the same time, it seems a bit hard to see but that may be because of the engineers I know.” To understand her point better, she was asked what engineers she knows and how she knows them. “Through robotics. One of them, she does biomedical engineering so she had done something working with prosthetics and figuring out whether or not, having for a shoulder, if the ball and socket were reversed, what the pros and what
4.10 Phase 2 – Describing How Engineers Are Related to Designers and Scientists

Focusing on how these students describe the similarities and differences between engineers and both designers and scientists will help determine how these students’ describe the work of a professional engineer. During the interview, the participants were asked to 1) describe the work of a designer and how it is similar and different to engineers; and 2) describe the work of a scientist and how it is similar and different to engineers.

4.10.1 Designers versus engineers

The concept that designers are responsible for taking an idea and then making sketches or plans of that idea is the dominant theme that emerged from these students. In addition to this theme, it was clear that the designs designers produce would need to be visually appealing to the public or whoever it was that wanted the design. “For me, it would be like someone creating something from their mind or what they have been given and kind of just, drawing or creating something out of it,” is how Rochelle describes the work of a designer and clearly supports the concept that designers specialize in the mental components of planning. Miranda offers additional details about the work of a designer by saying “I think they do a lot of planning and, like, knowing what people are interested in so that they could design something that would appeal to them. Um, like computer designing or designing websites and stuff.” The concept of creating drawings or plans was discussed by five interview participants, including Sean who followed up the claim by
offering that designers might work at a place like Lego so they can design products that people would purchase. Mica’s description of the work of a designer, after asking permission to refer to her experience with the Robotics team, offered specific details about how a designer would work in this context.

“So, with robotics, we have the people who do CAD, so that’s doing digital imaging on the computer and when I think about a designer, I think of that and that’s figuring out the shape of what you want it to be and what size. Then, figuring out what pieces you want but they have to work with an engineer to figure that out.” [Mica]

The context surrounding the term designer may have contributed to some confusion among the participants as the term is commonly used in multiple contexts. One student asked for clarification as he wanted to know if the question was asking to describe a technology designer or a clothing designer. After clarifying the question was not referring to a clothing designer, the response was “I think this is kind of what my dad does. He establishes new, um, eco-friendly ways a community can live. He designs ways that we can live more efficiently and that the community can grow as one” [Tara]. Jake did not ask for clarification and described the work of a designer as “it would be like either interior designing or outerier [exterior] designing of, maybe like what a yard would look like. Or how the interior of how a house should be. To make the house look more nice. Maybe, give the buyer more attention to the house.” From this response, Jake might be describing the work of an interior designer which is an interesting result but was not the original intention of the question.

Engineers and designers are similar as they both have to plan and are trying to create something new. This similarity was mentioned by Sean and Miranda, who then followed
up with “I always thought that designers were engineers. I don’t know. They both have to plan things kind of”. [Miranda] This comment suggests that engineers and designers might actually be the same thing. The only other response that specifically discussed how engineers and designers are similar was when Conrad offered that;

“They are both kind of construction, I guess. They’re both kind of doing the same thing, just, I feel like one is more educated about what, um, how things work. A designer kind of just, well he’s still educated but like, he just is more around designing everything.”

Conrad supports Miranda’s notion that they do the same thing but that they are just educated on different things. The major response that emerged wasn’t about how designers and engineers were similar but was more focused on how they would work together towards one goal.

“They probably have to work together in some form because, like, the designer would design the building and the engineer would give, like, tips or, mathematical stuff to that. Kind of like help the designer. They would probably work together as a team to finish either, like, a project or something.” [Jake]

Jake’s views on how a designer and an engineer work together is very clear and summarizes the major emerging theme from this question and he makes reference as to how specifically an engineer would help a designer by using math. He also suggests that it is the engineer who is helping the designer.

The differences between a designer and an engineer were very clear. A designer is responsible for making a plan, drawing or sketching it on a computer, and then worrying about aesthetics. The engineer will look at the plan, get the flaws out, and then take a hands-
on approach to actually turn that plan or drawing into reality. Rylan best described the differences between the two by saying “well the designer makes the plans sort of while the engineer start things in motion. Engineers are, I think, the people that actually do it versus designers who are the people that kind of make the plans with the engineers.” Jenna starts off her response by saying she isn’t sure about the difference but then supports Rylan with “I think a designer, you, it feels like you are only designing the part, just on a computer or on a drawing but when I think engineering, you think of them actually turning that drawing or design into the, like, building the thing itself, I guess.” These two responses support a very clear message towards these students’ perceptions as they indicated that engineers take a design from a designer and physically do something with it.

### 4.10.2 Scientist versus engineers

Describing scientists and the work they do and then following up with how they are similar and different to engineers will hopefully provide another angle to view these students’ perceptions. As discussed in Chapter 2, the research behind students’ perceptions of scientists has been happening for decades and has provided valuable information. Asking the interview participants in this study to first describe a scientist will provide insight into how they view scientists and can possibly be used for comparative discussions.

A scientist, as described by these students, is someone who tries to figure out new things in the world or things that need further exploring. To do that, they need to find new theories and background knowledge to support their ideas. A sample of the qualitative responses describing the work of a scientist is presented in Table 16. These descriptions of a scientist cover a wide range and are consistent with those discussed within Chapter 2.
Table 16: Students' descriptions of scientists and the work they do

<table>
<thead>
<tr>
<th>Student</th>
<th>Responses describing scientists</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rylan</td>
<td>“You can work with biology, chemistry, physics and all that but I feel like scientists are people who work towards trying to explain things using the different types of sciences. Or use science to help improve things”</td>
</tr>
<tr>
<td>Brad</td>
<td>“discovering new elements, or putting an end to global warming”</td>
</tr>
<tr>
<td>Conrad</td>
<td>“work outdoors on weather conditions and/or plants”</td>
</tr>
<tr>
<td>Sean</td>
<td>“work with the earth or developing drugs”</td>
</tr>
<tr>
<td>Jake</td>
<td>“work in a lab with chemicals or blood”</td>
</tr>
<tr>
<td>Tara</td>
<td>“work on vaccines, on genetically modifying foods, or on figuring how to do work on the ozone. Just a whole bunch of different things”</td>
</tr>
</tbody>
</table>

Scientists are similar to engineers in that they both use science, math, and formulas to discover things, to improve things, and to do their jobs. “When I think of it, they’re both working to improve things. That’s kind of like a common goal is. Whether it’s to improve maybe the efficiency of vehicles or how fast food is grown”. [Mica] Similar to the relationship with engineers and designers, Rochelle said that “I think a majority of what scientists do is what engineers would do” which might suggest they actually do the same thing or that the students have unclear views about what each actually do.

The uncertainty about how scientists and engineers would be similar also emerged from the responses. When describing the similarities between the two professions, Jake offers;

“Umm, not as much as a designer, I think, but, like, ah, he would still need like all the, umm, just in case, like if your, I don’t know. Just like, maybe if you're either, like, working on a project and, like, you need a scientist who can either help you with, like, if you can go through this or whatever, and do that in one certain area, you might need a scientist to help you out with that. To see if that’s proper to do that. Ya” [Jake]
This level of uncertainty when describing the similarities between engineers and scientists may suggest that the students are aware of a relationship between the two but struggle to offer a clear description.

Pinpointing how scientists and engineers are different appeared to be quite challenging for these students as the number of filler words and incomplete sentences was much higher than in any other question. Comments such as “engineers work on one thing and scientists work on another” [Brad] or “I don’t think they would be different as I think that scientists would actually fall underneath the category of an engineer” [Rochelle] indicate a lack of clarity about the differences between these professions. Similar to the emerging relationship between designers and engineers, the interview participants indicated that scientists and engineers actually work together. A scientist tries to find out new things, study the theory about those things, and engineers use the science and knowledge to put it into action. The last difference that was suggested between engineers and scientists is that “scientists are thought of a little bit more in a wide range of view. Like if you had engineers and scientists then, I think, you would think that a little more highly about a scientists because you don’t have as much background information on engineers”. [Ginny] This comment about the idea that scientists are more highly regarded than engineers might provide a supporting link to the result from phase 1 in which students indicated how much knowledge they have about different professions. From this question, engineers were at the bottom of the list, just below scientists. With the students’ self-identified level of knowledge about the engineering profession being the lowest of seven professions, the last segment of the interview was focused on determining the sources of these students’ perceptions.
4.11 Phase 2 – Sources of Perceptions

Identifying how people develop a perception and the sources that contribute to those perceptions has already been discussed within chapter 2. Within the interview, the students were asked to expand on how they believe they formed their understanding about engineering. The students were then asked to describe any exposure they might have previously had to engineering; and then to reflect on an answer from phase 1 about their intentions to study engineering at a post-secondary level and discuss if it has changed.

The self-identified sources of how these students formed their understanding about engineering included immediate and extended family members, courses in school, extracurricular opportunities, general interest, and the media. These students identified that immediate family members are the major source contributing to their understanding about engineering. However, the broad range of sources aligns and supports those discussed in Chapter 2. Six interview participants indicated that an immediate family member contributed to their level of knowledge and the breakdown consisted of four fathers, one mother, and one sibling. Although fathers emerged to be the most frequently credited source, the description of the father’s background and as to how the father may have influenced their understanding varied widely. One father, who is a financial analyst, likes doing things hands-on and figuring out how things would work, while another works with underwater construction. Another student gave credit to her father for her understanding about engineering, and shared that he works at Bombardier designing trains and train systems. “Usually I hear a lot from him about working on this project, accomplishing this, or this team did this”. [Miranda] The exposure to engineering that Miranda’s father is
providing her might be different than other students’ fathers and highlights the importance of immediate family members and the messages they provide.

Students’ exposure to engineering can come on multiple levels and can be dependent on several factors. Depending on the form of exposure, some students might not have the opportunity to learn about engineering. For example, if an opportunity to learn about engineering is an extracurricular program run after regular school hours, on weekends, or in the summer, some students may not be able to attend. In addition to a scheduling conflict, the cost of an extracurricular opportunity may limit a student.

When the phase 2 students were asked to describe their exposure to engineering, three students indicated that they participated in an extracurricular club or summer camp. All eight other participants indicated that they had very little, to no real exposure to engineering. To further investigate the level of exposure to engineering that students receive within their school, the students were asked the direct question and then provided their insight. The consistent message that emerged was that there isn’t really any opportunities. When asked to describe if there is any exposure to engineering in her school, Miranda offers;

“Not exactly. I guess in textbooks they say like, oh this engineer, if he did this what would happen but it doesn’t really explain it. The teachers don’t really explain much about what engineers do specifically. I guess because I am in Grade 9 they don’t talk too much about career choices as much as they would in Grade 11 and 12.” [Miranda]

An interesting point about Miranda’s response is that she believes that in Grade 11 and 12, there will be more communication about the different careers. In support of
Miranda’ comment, Rochelle adds that there is “not as much [exposure to engineering] as I think there should be. There’s no real exposure to it. Personally I don’t really know that much about it but I know that it’s a really really big deal for a lot of things.” The recognition the students are making about engineering being important and the lack of exposure to the profession being provided to them raises some interesting points. These points are addressed further in Chapter 7 and 8.

The final question from the phase 2 interviews revisited one of the questions from phase 1 in which the students were asked to identify their intentions to study engineering at a post-secondary level by selecting either ‘Definitely not’, ‘Probably not’, ‘Probably’, or ‘Definitely’. As discussed earlier in this chapter, the responses that were provided were also used when selecting which participants to interview in order to have at least one student from each intention level. The results of this question will be presented starting with the students who said they are definitely interested in studying engineering and working towards definitely not.

Of the eleven interview participants, Conrad, Jenny, Mica, and Sean indicated on the phase 1 questionnaire that they were definitely interested in studying engineering after high school. When asked at the end of the phase 2 interview, all except Sean said they were still definitely interested in studying to become an engineer. Conrad and Mica even mentioned that it is probably higher now that they have read the definitions and found out more about what engineers do. When asked why they had made their original decision, Conrad gave credit to his father, who is a marine engineer, and said that he really likes what he does and always thought that his dad would have to hire someone to do the engineering part in the future. Jenna, who has been certain about her intentions to study
engineering and who has displayed a high level of interest for the profession, supported her reasoning by saying that she has always been “interested in making stuff”, Math and Science are her favorite subjects, and being on different robotics teams has been her passion. She closes with; “I love doing it [robotics]. To be able to do that as a profession would be pretty awesome.”

Sean however said that his answer would be changed to a ‘probably’ now as opposed to definitely. When asked why it has changed, he answered with “maybe I’m just not as creative. It seems like you’re trying to meet people’s needs and work with companies. I’m not entirely sure but it just doesn’t seem as appealing anymore.” [Sean]

Two students, Brad and Jake, indicated in phase 1 that they were probably considering studying engineering after high school and three students, Ginny, Miranda, and Rochelle, initially said probably not. At the end of the interview, all five of them indicated that they are considering it a lot more now that they have a better understanding of what it is. Ginny, who originally stated she was probably not going to study engineering, responded in the interview by saying, “I think it is being considered a lot more for me because I didn’t have as much knowledge about the job or about the jobs they do. Until now, until this study. Whereas before it wasn’t brought up as much and it was more healthcare and the other jobs that are always brought up a lot more.” The idea of being exposed to the definition of engineering or increasing exposure to the profession in general as having a positive impact on these students is supported by Miranda’s comment of “it’s sort of widened my perspective on what engineers do and I see it’s for a good cause and I think that is pretty cool,” or when Rochelle was asked why she originally said she was
‘probably not’ going to study engineering, she said “because I wasn’t educated enough on it, but now it is a possibility.”

The final two students, Rylan and Tara were ‘definitely not’ interested in studying engineering in phase 1 and, when asked if their intentions had changed, they said that they had not. Rylan justifies his reasoning by offering “Well, I know more about it now but it’s still the same. I am not interested in going into engineering more because of the fact that I already do have a plan and I know what I want to do.” Both Rylan and Tara discussed the fact that they already have a career path in mind and it doesn’t involve engineering. When asked to expand on what he meant by knowing more about engineering now, Rylan added “well, from doing the interview obviously and reading those two definitions I know more now than I did before. More what people think and expect of engineers and it’s interesting to know now but it doesn’t influence my decision on going into engineering.” [Rylan]

Although both of these students indicated they have an increased level of knowledge about engineering, their original career path is more desirable. In the end, the student is clearly more capable of making an informed decision about which career path to choose.

Closing out the results section is a statement from Jenna who at the end of her interview, when asked if there was anything else she wanted to add, said;

“Well I think for people to get into engineering, if they get enough exposure at a young age like I did, then, a lot of people would be more interested. A lot of people just think it’s just math and science and you have to be really good at it, but you don’t have to, there is stuff you can do without the math. Well, you need basics but, you don’t have to be super good at it like a mathematician. And I think anyone can go into engineering if they have the passion for it.” [Jenna]
4.12 Triangulation from phase 1 and phase 2

As discussed in Chapter 3, one form of data triangulation used in this study was to ask some of the same questions and topics from the phase 1 questionnaire, in the phase 2 interviews. By including this form of triangulation, it increases the trustworthiness of this study [37]. The data from both instruments were analyzed separately which allowed for categories and common themes to emerge and then be compared. Three examples of the responses from phase 1 and phase 2 are presented Table 17 and support how the triangulated responses increase the trustworthiness of this study.

Table 17: Examples of triangulated responses

<table>
<thead>
<tr>
<th>Person</th>
<th>Phase 1 response</th>
<th>Phase 2 response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conrad</td>
<td>Figures out how to make whatever they are building how to make it strong and long lasting.</td>
<td>“Find out the best way to build or design something; find out how it can withstand stuff (ex. CN tower. Trying to build it so it can sway side to side without cracking). “</td>
</tr>
<tr>
<td>Miranda</td>
<td>A professional engineer is someone who creates, designs, or fixes something (most likely technology) to make life easier or more interesting for people.</td>
<td>&quot;Design and build things that work help people in today's society; they work on something - they have an idea, plan it out and then test it, if that works then they build whatever it is they're planning”</td>
</tr>
<tr>
<td>Jenna</td>
<td>Depending on the type of engineer. for a chemical engineer they take raw materials and using chemical reactions and properties to make them into useful stuff for a mechanical engineer they design and create lots of everyday buildings</td>
<td>“It depends on the type of engineer; chemical engineers work with chemicals to make a prototype from small scale into large scale. They make anything from laundry detergent to care fuels; civil and mechanical engineer build bridges and buildings; electrical work with electrical stuff; programming you're programming stuff from cars, to robots, to simple machines.”</td>
</tr>
</tbody>
</table>
Chapter 5

Discussion

The purpose of this research study was to describe the level of knowledge and/or perceptions that Grades 9 and Grade 10 students have about the engineering profession by addressing the following questions:

1. How do these students describe the engineering profession?
2. How do these students describe the work of professional engineers?
3. How do these students describe the relationship between engineers and designers?

Chapter 1 of this thesis provided an introduction to the research study, addressing several topics within the “Ask” component of the engineering design process (e.g., the problem statement and purpose of the study). The “Imagine” component of the design process was discussed in Chapter 2. This included a review of the relevant literature related to students’ perceptions of engineering. Chapter 3, the “Plan, Test, and Create” component described the research design. Chapter 4 presented the results and Chapter 5 will discuss the “Evaluate and Improve” component of the engineering design process. To do this, the results from this study will be explained, along with how they link to previous research. The limitations of this research, final conclusions, implications and recommendations for educators and researchers, as well as future research will be discussed in Chapter 6 and 7.
5.1 Students’ Perceptions of Engineering and Professional Engineering Work

The first two research questions in this study were designed to determine these students’ perceptions of engineering and the work engineers do. This section will discuss the first two research questions and will highlight significant differences between the four factors of interest (grade, gender, school, relationship with an engineer). This section will also discuss how the results relate to other studies, literature definitions for engineering and the work of engineers, and finally, the CEAB graduate attributes.

5.1.1 Engineering involves designing, creating, and building

When the students described engineers and the work they do, they used words that have to do with the ‘Central Creative Process’ (CCP) of engineering. For example, they often included the words ‘design’, ‘create’, ‘innovation’, and ‘build’, suggesting that the students have an understanding of the mental and physical aspects of engineering. This was supported by the high percentages of students who correctly identified, which job descriptions represent typical engineering activities. Table 18 contains the job descriptions that include the words from the CCP categories, the percentage of students who correctly identified them from this study, and from Cunningham’s study [26].

Table 18: Correctly Identified Engineering Job Descriptions Related to the CCP Category

<table>
<thead>
<tr>
<th>Job description</th>
<th>Typical engineering activity?</th>
<th>% Correct</th>
<th>Cunningham’s Study - (pre) % Correct</th>
<th>Cunningham’s Study - (post) % Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improves machines</td>
<td>Yes</td>
<td>95.6</td>
<td>68.0</td>
<td>78.0</td>
</tr>
<tr>
<td>Design things</td>
<td>Yes</td>
<td>90.7</td>
<td>36.9</td>
<td>76.2</td>
</tr>
<tr>
<td>Read about inventions</td>
<td>Yes</td>
<td>85.6</td>
<td>18.4</td>
<td>32.7</td>
</tr>
<tr>
<td>Design ways to clean water</td>
<td>Yes</td>
<td>77.3</td>
<td>36.6</td>
<td>76.8</td>
</tr>
</tbody>
</table>
Over 75% of students in this study correctly identifying that these four job descriptions represent typical engineering activities, this suggests that they are aware that engineering involves the aspects of the CCP category. The 97 students in this study were more aware of the job descriptions that use words from the CCP category versus the 5139 students from six different states across the US in Cunningham’s pre-intervention study [26]. This result is logical, given that the students in this study are older (Grades 9 and 10 versus Grades 2 through Grade 6). Looking at the post-intervention results from Cunningham’s study, the percentage of students who correctly identified these job descriptions was much closer to the results from this study. This suggests that the students’ in this study’s awareness of engineering work involving aspects of the CCP category are more aligned with the students in Cunningham’s study, after an engineering intervention. While Cunningham’s study was conducted in the US, this difference in awareness may reflect differences in curriculum between grades, rather than countries. Although a direct comparison to Cunningham’s research study is not possible due to variances of the American curriculum as well as the different grade levels, it is, nevertheless, valuable insight into these students’ perceptions of engineering.

When identifying the attributes that best describe engineers, the students in this study also used words that have to do with the CCP of engineering. Two of the top five attributes (out of a list of twenty-four) identified by the students in this study, include the words ‘design’ and ‘build’ (Table 19). These two attributes to describe engineers were also in the top five indicated by teens in a research study by the National Academy of Engineering (NAE) [5].
Table 19: Attributes to describe engineers compared to NAE’s study

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Ranking</th>
<th>Literature Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardworking</td>
<td>1&lt;sup&gt;st&lt;/sup&gt;</td>
<td>3&lt;sup&gt;rd&lt;/sup&gt; (Tie)</td>
</tr>
<tr>
<td>Good at Math and Science</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt;</td>
<td>1&lt;sup&gt;st&lt;/sup&gt;</td>
</tr>
<tr>
<td>Problem Solvers</td>
<td>3&lt;sup&gt;rd&lt;/sup&gt;</td>
<td>3&lt;sup&gt;rd&lt;/sup&gt; (Tie)</td>
</tr>
<tr>
<td>Designs, draws, plans</td>
<td>4&lt;sup&gt;th&lt;/sup&gt;</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt;</td>
</tr>
<tr>
<td>Build, construct, make things</td>
<td>5&lt;sup&gt;th&lt;/sup&gt;</td>
<td>5&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

One possible reason as to why the CCP categories were not in the top three attributes (Table 19), which would align with the results discussed above, could be that these students assumed engineers are ‘hardworking’, ‘good at math and science’, and ‘problem solvers’. By making this assumption, it would allow for the students’ first thoughts when describing engineering to focus on the mental and physical aspects of the CCP category.

Using the words ‘design’ or ‘create’ to describe engineering was the major theme that emerged from the NAE’s study *Raising Public Awareness of Engineering* [22] and from Montfort’s study with secondary students [36]. It should be noted that in Montfort’s study, the students had received a formal intervention about engineering. The post-intervention recognition that engineering involves words that have to do with the CCP category was also noticed in other research, two with middle school students [31] [34], and several with elementary school students [24] [26] [28] [46]. Even though these research studies were conducted with a younger student population, the students (after intervention) described engineering using words from the CCP category. Within the NAE’s study [5], where the teens did not receive any engineering intervention, the word ‘design’ from the CCP category was the fifth most frequently mentioned. The results from this study are consistent with the research studies noted above and suggest that these students, who did
not receive any formal intervention, have a strong sense that engineering involves designing, creating, and building.

In addition to the previously mentioned theme, it is interesting to note the complexity of the context or environment that some of these students used to described engineers. The word ‘building’ was usually grouped within the physical aspect of the CCP category, however, in some cases it was grouped within another category called ‘skilled trades’. For example, some students in this study used the word ‘building’ when referring to the physical manual labor of construction, while others referred to new forms of technology. When some students simply used the word ‘build’ without any description to describe engineering, it was challenging to interpret in which context they were referring to. The confusion around the physical aspect of ‘building’ and how it relates to engineering led to the second major theme from this study, the link between engineering and the skilled trades.

5.1.2 Engineering is linked to skilled trades

These students perception of engineering involves the use of tools to fix machines and cars, working on a construction site, with plumbing, or with electricity. These words could also be used to describe skilled trades. This suggests that these students have an understanding that engineers and skilled trade workers perform similar tasks. This perception about engineers is supported by the low percentage of students who correctly identified several typical engineering activities.

From the list of sixteen job descriptions, six of them have been identified as typical engineering activities (Table 11). Of those six, the ‘improve machines’ and ‘set up
factories’ were classified as typical engineering activities. The context or environment of these job descriptions that do describe typical engineering activity could be an example of how confusion can occur, as these descriptions include the words ‘machine’ or ‘factory’. If these words were to have been used without any additional information, it is possible that they would have been grouped within the ‘skilled trades’ category.

For the job descriptions that were not classified as typical engineering activities, three of them (indicated by an * in Table 20) could arguably be classified as such. For example, ‘Supervise construction’ could be classified as a typical engineering activity, because there is a reasonable possibility that an engineer (especially civil or mechanical) could end up in a construction supervisory role. However, the context of the supervision would be different from that of a ‘foreman’, which would typically be a skilled trade position. Table 20 illustrates the percentage of students who correctly identified that these five job descriptions do not describe typical engineering activity, along with the results from Cunningham’s study [26].

Table 20: Correctly Identified Job Descriptions of Engineering Related to Skilled Trades

<table>
<thead>
<tr>
<th>Job description</th>
<th>Typical engineering activity?</th>
<th>% Correct</th>
<th>Cunningham’s Study - (pre) % Correct</th>
<th>Cunningham’s Study - (post) % Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drive machines</td>
<td>No</td>
<td>47.4</td>
<td>29.4</td>
<td>57.7</td>
</tr>
<tr>
<td>Repair cars</td>
<td>No</td>
<td>36.1</td>
<td>22.0</td>
<td>46.7</td>
</tr>
<tr>
<td>Construct buildings</td>
<td>No*</td>
<td>35.1</td>
<td>21.9</td>
<td>43.5</td>
</tr>
<tr>
<td>Supervise construction</td>
<td>No*</td>
<td>34.0</td>
<td>47.9</td>
<td>51.9</td>
</tr>
<tr>
<td>Install wiring</td>
<td>No*</td>
<td>32.0</td>
<td>21.8</td>
<td>46.4</td>
</tr>
</tbody>
</table>

These low percentages of students who correctly identified that these five job descriptions do not describe typical engineering activities suggest that over half of these
students are unclear about what engineers do. Considering that these descriptions more accurately represent typical skilled trades such as an electrician or a mechanic, it indicates that these students confuse the work of engineers with trades. Comparing the results from this study to Cunningham’s study (pre-interventions) [26], the percentage of students who correctly identified that these job descriptions do not represent typical engineering activities is very similar. For ‘Supervise construction’, the percentage of Grades 9 and 10 students from this study who correctly identified the job descriptions, is lower than that of Grades 2 through 6 students in Cunningham’s study. The percentage of students who correctly identified these job descriptions post-intervention from Cunningham’s study, although still only around 50%, significantly increased. With the percentages from this study with Grades 9 and 10 students located between Cunningham’s pre and post intervention results with students in Grades 2 through 6 [26], this suggests that the students in this study have comparable views about engineering to elementary students in relation to jobs that could also be described as skilled trades.

This lack of clarity between what engineers and skilled trades workers do has been reported in previous research [36] [31] [24] [28] [29] [27] [32]. Therefore, this study is consistent with the literature in students recognizing similar activities between engineers and the skilled trades.

5.1.3 Engineering includes Science, Technology, and Mathematics

When these students described engineering, they often mentioned the subjects Science, Technology, and Mathematics, suggesting a recognition that engineering involves a knowledge base in these STM subjects. However, very few students were able to provide
specific examples as to how they are connected. Hence, it is reasonable to assume that these students are unaware of how engineers might use or apply these subjects.

This perception is consistent, to various degrees, with other research studies [5] [36] [24] [32] [33]. One possible reason as to why these students appear to be aware of a link between these three subjects and engineering might be due to the increasing use of the STEM acronym within schools. The increased use of the STEM acronym could be directly and/or indirectly providing exposure to a connection between these four subjects.

Adding to the complexity of the connection between engineers and skilled trades is the broad spectrum of subjects that fall under the ‘Technology’ umbrella. Within the Ontario curriculum, Technological Education encompasses ten different subject areas such as ‘Communications Technology’ and ‘Computer Technology’ but also includes ‘Construction Technology’ and ‘Manufacturing Technology’. Some of these courses are designed for students in the academic stream and provide a direct advantage for applying to study engineering, while others are designed for students within the college or workplace stream. Therefore, by using the word ‘Technology’, it is possible that these students are using incomplete knowledge about some of these courses to generate their perception of engineering. These perceptions might not be consistent with the true definition or application of the engineering profession.

5.1.4 Engineering work helps people or the environment

Some students in this study described engineers and the impact they have on people’s lives, or the environment. This suggests an understanding of the connection between engineers and society. The role of an engineer in helping the community has been
reported in a few studies [36] [34] [28], but within the NAE’s study [22], engineers were not recognized as contributing to the public’s quality of life and the environment. This inconsistent result across research might suggest that the link between engineers and helping people or the environment is not being made. Within a literature definition for engineering [19], the description of engineering work [20], and the CEAB graduate attributes [21], this relationship between engineers and helping people and/or the environment is explicitly mentioned, and is therefore important to the profession. While it is notable that very few participants were aware of this attribute of engineering, this may arguably reflect on the lack of awareness of engineering within Canadian society in general.

5.1.5 Engineers are problem solvers

The final clear perception that emerged from this study is that Engineers are problem solvers. However, there were some inconsistencies between two of the questions on the questionnaire. From one question, the phrase ‘solving problems’ was mentioned by only a few students, but when selecting the attributes that best describe engineers, it was the third highest (Table 19). The ranking of ‘problem solvers’ as the third highest attribute was consistent between this study and from the teens in the NAE’s study [5].

The recognition that engineering involves solving real-world problems was a theme that emerged from other studies [31] [34] [47], including being a major theme from Hirsch’s study with high school students [48]. However, the difference between these research studies and this study, in addition to the participants’ grade level, is that these students did not receive any intervention regarding engineering.
5.1.6 Significant differences between the four factors

These students’ perceptions of engineering were analyzed to determine if any significant differences existed between grade, gender, school, and knowing an engineer. These factors were not key research topics in this study, however the data illustrates interesting perceptions that may provide insight for future research.

When describing the work of an engineer, or when correctly identifying which job descriptions are typical engineering activities, there was no significant difference between the male or female participants. However, the female students were significantly more likely to associate the attribute ‘builds, constructs, or makes things’ with engineers, compared to the male participants and is supported by a medium Cohen’s effect size. This result suggests that these female students are more likely to associate the work of an engineer with physical attributes.

The Grade 10 students were significantly more likely than the Grade 9 students in this study to use the words from the CCP category, as well as suggest that engineers help people or the environment. One possible reason for this difference, which could be explored further in another study, is that Grade 10 students in Ontario take a mandatory half-credit class focused on exploring different careers and may have obtained new knowledge about the engineering profession.

The students at School E (which had the lowest SES catchment area) and the students at School D (a rural school) were significantly more likely to use words that also describe skilled trade workers, and emphasized ‘Technological Education’ when describing engineering. One possible reason for these results is that the students at School D and E might have different exposure levels or values when viewing ‘Technological
Education’. The students at School E were also significantly less likely to describe engineering as related to solving problems and involving Science or Math. These results suggest that the location of the school (which in this study includes the SES catchment area of the school and whether it is urban or rural) has an impact on students’ perception of engineering.

The self-identified relationship between the participants and knowing an engineer was the final factor analyzed to determine if the relationship to an engineer impact students’ perceptions. The results from this study suggest that the participants who did not know an engineer were less likely to describe engineers using the STM subjects or as problem-solvers. This suggests that because the students have a relationship with an engineer (either family or personal), they have more exposure and possibly more knowledge about the profession. However, when attempting to correctly identify the job descriptions that describe typical engineering activity (Table 11), knowing an engineering did not lead to more accurate answers. Because there was no significant differences between knowing and not knowing an engineer with respect to job descriptions, it suggests that these students are equally unclear about what engineers do.

5.1.7 Students’ perceptions related to the literature definitions and CEAB attributes

Engineering, as defined by Tom Brzustowski in Chapter 2, can be dissected into the five components of: creating; designing; scientific knowledge; economic considerations; and public safety [19]. Engineers Canada’s description of what professional engineers do was also presented in Chapter 2 and can be separated into these other five components of designing; protecting the environment; helping people; public safety; and managing world-leading companies [20]. These students’ perceptions of
engineering did not mention the components of engineering related to economic considerations, public safety, managing companies, and to some extent, helping people. Since these components are important enough to the engineering profession to be specifically highlighted within Engineers Canada’s description of engineering work, they should arguably be part of the conversation around engineering at an earlier stage.

Mapping these students’ perceptions of engineering onto the twelve CEAB graduate attributes [21] also provides useful information. The major perceptions that emerged from this study were that engineering involves a strong knowledge base in Math and Science (attribute 1) and design (attribute 4). The minor perceptions suggested that some students are also aware that engineering involves problem analysis (attribute 2), as well as help people, society, and the environment (attribute 9). In total, four of the twelve attributes were discussed (to varying degrees) by these high school participants. However, since all twelve attributes are important to the engineering profession, it would be useful to integrate them into information provided to prospective students.

5.2 Students’ Perceptions of the Relationship between Engineers and Designers

The final research question that this study was designed to determine is how these students perceive the relationship between engineers and designers. This section will discuss this research question and highlight how these students view the differences between engineers and designers. As an extension to this research question, the relationship between how these students view engineers and scientists will also be discussed.
5.2.1 Self-identified knowledge about engineers, designers, and scientists

When asked to self-identify their level of knowledge about seven different professions (teacher, doctor, designer, lawyer, architect, scientist, and engineer), the students in this study identified that they know the least about engineering. The results were previously presented in Chapter 4, but the relative order of professions from the students in this study, compared to that of the teens in the NAE’s study [5], is presented in Table 21. While not used in the NAE’s study, ‘Designer’ was added to this study to see how the students rate their level of knowledge about designers and how it compares to the other professions.

Table 21: Self-Identified Ranking and NAE’s Ranking about Different Professions

<table>
<thead>
<tr>
<th>Profession</th>
<th>Relative Order</th>
<th>NAE’s Study Order</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher</td>
<td>1&lt;sup&gt;st&lt;/sup&gt;</td>
<td>1&lt;sup&gt;st&lt;/sup&gt;</td>
</tr>
<tr>
<td>Doctor</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt;</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt;</td>
</tr>
<tr>
<td>Designer</td>
<td>3&lt;sup&gt;rd&lt;/sup&gt;</td>
<td>N/A</td>
</tr>
<tr>
<td>Lawyer</td>
<td>4&lt;sup&gt;th&lt;/sup&gt;</td>
<td>3&lt;sup&gt;rd&lt;/sup&gt;</td>
</tr>
<tr>
<td>Architect</td>
<td>5&lt;sup&gt;th&lt;/sup&gt;</td>
<td>5&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td>Scientist</td>
<td>6&lt;sup&gt;th&lt;/sup&gt;</td>
<td>4&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Engineer</strong></td>
<td><strong>7&lt;sup&gt;th&lt;/sup&gt;</strong></td>
<td><strong>6&lt;sup&gt;th&lt;/sup&gt;</strong></td>
</tr>
</tbody>
</table>

Teachers and doctors were at the top of the list which is not surprising given the exposure students have to these professions. According to these students, they know more about what a designer does than they do about lawyers. Notwithstanding the inclusion of ‘designer’, this relative order of professions is consistent with the NAE’s study and both studies indicate that the students/teens know the least about what engineers do. Although the differences between the seven professions were not statistically significant, the self-
identified low-level of knowledge about engineering suggests that these students have unclear views about the profession.

5.2.2 Designers are creative and innovative

When these students were asked to described designers, they used words that have to do with the mental aspect of the CCP. For example, they would often use the words ‘create’, and ‘innovate’, which suggests that these students have an understanding that designers need to be creative. Like engineering, a designer can specialize in different fields and the classification of ‘designer’ is used in multiple scenarios. Because of these multiple scenarios, some of these students described designers in the context that related to clothing, fashion, or decorating a house. This interesting result provided insight into students’ perceptions of the word designer. For future studies, if the context in which the participants are asked to describe a designer is important, it is necessary to design the question to include more explicit details within the question.

5.2.3 Differences between engineers and designers

When describing the differences between designers and engineers, it was very clear that these participants believe designers are the source of an innovative idea and create the plan while considering the aesthetics of the plan. Likewise, they believe engineers take a hands-on approach and put that plan into action by building it. In other words, designers focus on the mental aspect of the CCP category while the engineers focus on the physical aspect. In some cases, their descriptions were suggestive that engineers cross into the ‘skilled trades’ category. These results seem to suggest, from the students’ perspective, that engineers are not sources of new and innovative ideas or plans.
The distinct classification of engineers as ‘doers’ is consistent with Fralick’s study with middle school students [32]. The significance of this perception is that the physical act of ‘doing’ something is potentially linked to skilled trades work and a contributing factor towards unclear views about engineering.

5.2.4 Differences between engineers and scientists

The relationship between engineers and scientists was not specifically one of the research questions for this study but was included within the interviews to collect further insight into these students’ perceptions of engineering.

When describing the differences between engineers and scientists, the participants believe that scientists are the ones who try to find out new things and study the theory behind them while engineers apply the new science and knowledge. Similar to these students’ perceptions about the relationship between designers and engineers, they perceive scientists to focus on the mental aspect of the CCP category and the engineers to focus on the physical aspect.

5.3 Students’ Self-identified Sources of Perceptions about Engineering

The word “perception”, as discussed within Chapter 2 of this study, refers to people’s direct recognition or understanding of the world, which is constructed from the information obtained by means of the senses. Forming a perception involves four fundamental elements [12] and follows a perceptual process [13]. Identifying the contributing factors to these students’ perception about engineering was not one of the intended research questions for this study, but it was decided that by asking the students to describe the sources, it might help to understand the origin of their perception. These
identified sources of perception can be linked back to the literature as they represent ‘the stimuli by the senses’ or the ‘context of the situation’ which are two of the four fundamental elements to forming a perception [12].

The five self-identified sources of how these students formed their understanding about engineering include family members, courses in school, extracurricular activities, general interest, and the media. The major self-identified source of engineering knowledge was obtained through an immediate family member, which is consistent with Oware’s study with elementary students [28]. In this discussion, the external and extracurricular factors that might influence a student’s perception, such as the role of a family member, the media, or summer outreach programs, will not be addressed. Instead, this discussion will focus on the exposure to engineering that students might receive in a traditional classroom or school setting. The rationale for this decision was that within a traditional classroom or school setting within Ontario, students are taught the same base curriculum and generally have access to similar learning opportunities.

Most students in this study indicated they had very little exposure to engineering and that there weren’t opportunities to learn about it in school. With very minimal, or in some cases non-existent, exposure opportunities to learn about engineering, students’ perception would heavily depend on external factors such as family and/or the media. Therefore, if the level of exposure to engineering within a traditional setting was increased, they could use their own discretion to construct a perception. Based on these students’ perceptions of engineering as supporting evidence, the argument can be made that these students might benefit from an increase in exposure to engineering.
Whether it was from the students’ own intrinsic motivation to learn about engineering because they were part of a study, or by reading the literature definitions described in Chapter 2, most students reported and increased interested in studying engineering by the end of the study. There was also one student whose intention to study engineering decreased. Both of these results suggest that if the student’s exposure and level of knowledge about engineering is increased, they will be better able to make an informed decision about whether their individual career pathway involves engineering.

5.4 Limitations of this Study

Within the design of this research study, there were three specific limitations that need to be acknowledged: 1) instrument design; 2) the researcher as the instrument; and 3) geographical location and sample size.

5.4.1 Instrument design: questionnaire and interviews

Some of the limitations when using a questionnaire for data collection purposes are that it does not provide an opportunity for the researcher to answer any questions the participants might have, or to clarify any of the participants’ responses, and that it relies solely on the participants’ interpretation of the question.

For this study, one limitation of having the participants describe their first thoughts about engineering may have been that they did not offer any secondary thoughts that might have contributed towards their complete perception. This limitation is similar to other research that involves having participants complete a DAET [7] as students may have multiple views about engineers but only described one of them. For future studies, the
question should be more specific when probing student’s view by asking them to describe ‘all’ of their thoughts about engineering.

These limitations were minimized by conducting follow-up interviews with several of the students but not all participants were interviewed.

5.4.2 Researcher as the instrument

As a solo researcher, there are several possible limitations when conducting a study, as well as strategies to minimize those limitations. In this study, the researcher had limited experience with questionnaire design, qualitative interviewing, and interpreting both quantitative and qualitative data of this nature. By using an inductive coding process to analyze the data, one of the limitations of this study may have been that some information was overlooked or misinterpreted. To minimize this limitation, a sample of the data was provided to an experience researcher for data triangulation purposes.

5.4.3 Geographic location and sample size

The final limitation for this study is that all five schools, although scattered across the Greater Kingston Area, are within one school board. Although this factor might have put limitations on this research study, isolated studies such as a case study, have indicated that a small sample size supported by rich, descriptive, qualitative accounts can yield insight into people’s experiences and conceptions [37].

By using a criteria-based sampling strategy for this study, the total possible number of eligible participants from each of the five schools varied and was another possible limitation.
Chapter 6

Conclusion

These students’ perceptions of engineering and the work of a professional engineer are an amalgamation of three other professions: designers; scientists; and skilled trade workers. In the open-ended responses, approximately 40% of the students described engineering as involving the mental aspects of designing or creating, approximately 30% suggested engineering requires knowledge in Math and Science, and approximately 28% mentioned the physical aspect of building. Fewer students also described engineering in relation to problem solving, and helping people or the environment. However, when unpacking these descriptions, these students were very clear that designers are the source of creative and innovative ideas and scientists are the source of new theories. Engineers are responsible for turning those creative ideas and/or the new theories into reality by physically building something. The perception that engineering involves building something was the major source of confusion about engineering for these students as many of them described engineers in roles that could also be used to describe skilled trades. For this reason, it can be concluded that these Grades 9 and 10 students have unclear views about engineering.

To help clarify these students perceptions about engineering, more awareness and exposure opportunities to accurate information about the profession are required. Through these opportunities, students will be able to make an informed decision about possible career paths, and decide if engineering might be a suitable path for their future.
Chapter 7

Implications and Recommendations

Students’ perceptions and understanding of engineering has been studied by several organizations and researchers across the United States, however, few studies have been completed within Canada. This research study was useful in learning about how these students in Grades 9 and 10, from one school board in Ontario, view the engineering profession. The results and discussion have led to several implications and recommendations for educators and researchers.

7.1 Educators

As educators are preparing to teach students about engineering, one possible starting point could be to conduct an ‘assessment for learning’ task such as having the students write a reflection piece about their pre-conceived ideas about engineering. Educators can then use these reflections of the students’ prior knowledge about engineering when designing and planning classes or intervention strategies to help clarify or expand on their perception. For example, the students in this study were aware that engineering involves STM subjects, and that engineer’s build/design, but had difficulty correctly identifying specific examples of engineering work. If these perceptions were similar to the reflections, educators could focus their attention towards helping students become more aware of engineering work and how it involves the students’ pre-conceived notions.

Another implication from this study is that educators could use Engineers Canada’s description of what engineers do, along with the CEAB graduate attributes to openly discuss engineering with students. The use of these descriptions will not only increase
students’ exposure to engineering, but can also be used to discuss how engineers are similar and different to designers, scientists, and skilled trades.

Since teachers influence students’ perceptions, increasing the number of professional development opportunities for teachers to learn about engineering is important. If teachers were provided with strategies to help students learn engineering concepts, such as the engineering design process, they might be able to better integrate engineering concepts into their classroom. The implications this would have for the diversity of the engineering profession could be significant as teachers are able to reach a large cross-section of students.

7.2 Researchers

For researchers, one implication from this study was the advantage of using a sequential multiple method approach for data collection. By using a questionnaire and interviews to collect data, the limitations of the individual instruments by themselves are minimized. It also provided the opportunity to use statistical analysis tools to compare results for significant differences between groups while allowing the participants to respond to open-ended questions. Another implication for researchers is to be specific about the wording of each question. For example, when this study asked students about essential subjects to study to become an engineer, ‘Technology’ was one option, but there are multiple courses that fall within this subject.

The transferability of this study is the responsibility of the reader. However, the researcher believes that since Ontario has a common curriculum and a similar school structure, it is reasonable to extrapolate these students’ perceptions and suggest that some
of these trends might exist province-wide. Therefore, the final implication for researchers is to use this naturalistic study to continue studying students’ perceptions in a positivist approach that will demonstrate reliability and generalizability.
Chapter 8

Future Research Recommendations

The purpose of this research was to determine Grade 9 and Grade 10 students’ perceptions of engineering and contribute to the greater body of literature around student perceptions of the profession. There are several recommendations for the continuation of this research, and for future research questions.

8.1 Instrument Refinement

In reviewing the data collection instruments, several of the questions asked the participants to describe their first thoughts about either engineers or designers. As discussed in the limitations, it is possible that the students were doing only that and not providing their secondary or complete thoughts. Therefore, it is recommended that the questions be modified to remind the participants to describe all thoughts related to the topic.

Another refinement from the questionnaire would be to add a follow up question that lists all of the ‘Technology’ subjects and ask students to clarify which ones are essential to take in school to become an engineer. This extension would provide further insight into how future participants view the relationship between engineers and skilled trades.

Increasing the use of probing questions to expand, clarify, and unpack students responses within the interview protocol will minimize the limitation of researcher interpretation. For example, if a student mentions that engineers ‘build’, a probing question asking the participant what specifically they build, or if engineers are physically doing the building, would help determine the context in which they are describing engineers.
Finally, after implementing the refinements to the instruments, expanding the participant population and diversity of this study to include multiple school boards within Ontario, is important. This expansion will provide further insight into how Grades 9 and 10 students, who are taught the same curriculum, perceive engineering. This study could then expand more broadly across Canada.

8.2 Future Research Questions

To develop a more complete view of students’ perceptions of engineering, there are three specific areas that contain multiple questions that would benefit from future research.

The first area for future research is with Engineers Canada which is the governing body for professional engineering within Canada. As a governing body, it should be important to provide accurate information to the general public, and especially students, about engineering. This research study provided some preliminary evidence that Grades 9 and 10 students are unaware of several aspects of engineering work that are included in Engineers Canada’s description. Therefore, there are three future research questions that might be worth exploring:

i. Does the current description of engineering work provided by Engineers Canada accurately represent the work of practicing professional engineers in Canada?

ii. Would multiple descriptions of engineering using age-appropriate language for specific target different audiences help provide clarity about the profession?
iii. Do high school students benefit from being exposed to the CEAB graduate attributes when considering engineering as a possible career path?

The second area for future research would be with Science and Math educators to investigate the opportunities students have to learn about engineering. There are two specific future research questions that would help understand if/how engineering is being taught in schools.

i. What opportunities are there within the current curriculum to provide exposure to engineering for students?

ii. Are teachers comfortable with incorporating engineering concepts into their Science or Math lessons?

The final area for future research is continue to explore how high school students view the engineering profession. One specific future research question that would be important to understand is:

i. How do students describe engineers in terms of ‘building’, and the relationship between engineers and skilled trades.
References


[34] L. D. English, P. B. Hudson and L. A. Dawes, "Middle school students' perceptions of engineering," in STEM in Education Conference, Brisbane, Qld, 2011.


[40] M. Spencer, "Engineering Perspectives of Grade 7-8 Students," Queen's University, Kingston, 2011.


Appendix A

Clearances and Approvals

A.1 General Research Ethics Board Clearance

A.2 Letter of Approval from School Boards
A.1 General Research Ethics Board Clearance

May 05, 2014

Mr. Scott Compeau  
Master's Student  
Department of Mechanical and Materials Engineering  
Queen's University  
Kingston, ON, K7L 3N6

GREB Ref #: GMECH-027-14; Romeo # 8012712  
Title: "GMECH-027-14 The Calling of an Engineer: High School Students' Perceptions of Engineering"

Dear Mr. Compeau:

The General Research Ethics Board (GREB), by means of a delegated board review, has cleared your proposal entitled "GMECH-027-14 The Calling of an Engineer: High School Students' Perceptions of Engineering" for ethical compliance with the Tri-Council Guidelines (TCPS) and Queen's ethics policies. In accordance with the Tri-Council Guidelines (article D.1.6) and Senate Terms of Reference (article G), your project has been cleared for one year. At the end of each year, the GREB will ask if your project has been completed and if not, what changes have occurred or will occur in the next year.

You are reminded of your obligation to advise the GREB, with a copy to your unit REB, of any adverse event(s) that occur during this one year period (access this form at https://eservices.queensu.ca/romeo_researcher/ and click Events - GREB Adverse Event Report). An adverse event includes, but is not limited to, a complaint, a change or unexpected event that alters the level of risk for the researcher or participants or situation that requires a substantial change in approach to a participant(s). You are also advised that all adverse events must be reported to the GREB within 48 hours.

You are also reminded that all changes that might affect human participants must be cleared by the GREB. For example you must report changes to the level of risk, applicant characteristics, and implementation of new procedures. To make an amendment, access the application at https://eservices.queensu.ca/romeo_researcher/ and click Events - GREB Amendment to Approved Study Form. These changes will automatically be sent to the Ethics Coordinator, Gail Irving, at the Office of Research Services or Irvingg@queensu.ca for further review and clearance by the GREB or GREB Chair.

On behalf of the General Research Ethics Board, I wish you continued success in your research.

Yours sincerely,

Joan Stevenson, Ph.D.  
Chair  
General Research Ethics Board  

cc: Dr. David Strong, Faculty Supervisor
May 22, 2014

Scott Compeau
Faculty of Engineering and Applied Science
45 Union Street, Room 300
Queen’s University
Kingston, ON
K7L 3N6

Dear Scott:


I am responding to your request to conduct a research project for the study “The Calling of an Engineer: High School Students Perceptions of Engineering” from Queen’s University in the Limestone District School Board. I have reviewed your materials, and approval is granted.

May I emphasize that in accordance with our Administrative Procedure 291: External Research participation in this research is entirely voluntary by the schools involved. Also, it is understood that for all research projects, the names of schools and students will not be identified in your final report, and schools and students have the right to opt out of this project at any time.

Best of luck on your research. I would appreciate a copy of your report when it is completed.

Sincerely,

Norah Marsh
Superintendent of Education
NM&AS

c C Brenda Hunter, Director of Education
    Secondary Principals, Secondary Schools

Laurie French – Chair | Brenda Hunter – Director of Education and Secretary | Paul Bubis – Treasurer
Appendix B
Letters of Information and Consent

B.1 Teacher Letter of Information

B.2 Student/Parent Letter of Information – Phase 1 Questionnaire

B.3 Student/Parent Letter of Information – Phase 2 Interview
B.1 Letter of Information for Teachers

TEACHER LETTER OF INFORMATION

The Calling of an Engineer: High School Students Perceptions of Engineering

This research is being conducted by Scott Compeau (Master of Applied Science, Candidate) under the supervision of Professor David Strong in the Faculty of Engineering and Applied Science at Queen’s University in Kingston, Ontario. This study has been granted clearance according to the recommended principles of Canadian ethics guidelines and Queen’s policies. The Limestone District School Board has also approved this study.

What is this study about? Over the past 20 years, the number of students entering engineering programs in North America has declined [49]. In 2010, only 6.4% of all bachelor's degrees earned in Canada [50] are in engineering. The purpose of this research is to understand the perceptions that grade 9 and grade 10 students, whom are enrolled in academic English, Mathematics, and Science courses, have about the engineering profession. In order to achieve the goal of understanding this phenomenon and guide the research, the exploratory research questions of 1) How do students perceive engineering, and 2) How do students perceive the work engineers do, must be asked.

What will this study require? If you agree to participate in this research, your involvement would be an integral part of the study as you will be asked to distribute and collect the consent forms. The students in your class (provided their guardians give consent) will first complete an online questionnaire (30 minutes maximum) on their own time. From the questionnaire, they will have the option to volunteer for a follow-up interview. In the second part of the study, I will be selecting, with your collaboration, a maximum of eight students for individual interviews, one of which may be in your class. Interviews will be conducted at your home school during regular class time, will last a maximum of one hour, and will be recorded in digital audio files.

Is participation voluntary? Your participation as well as the students is completely voluntary and choosing not to participate will not result in any adverse consequences. There are no known physical, psychological, economic, or social risks associated with this
study. Further, the students are free to choose, without reason or consequence, to refuse to answer any questions. They may withdraw from the study at any time with no negative consequences. If the students withdraw from the study, they may choose to have their data removed.

**What if I have concerns?** Any questions about study participation or a request to withdraw from the study may be directed to Scott Compeau at s.compeau@queensu.ca or my supervisor Professor David Strong at (613) 533-2606 or strongd@queensu.ca. Any ethical concerns about the study may be directed to the Chair of the General Research Ethics Board at (613) 533-6081 or chair.GREB@queensu.ca.
B.2 Letter of Information for Students

STUDENT LETTER OF INFORMATION – QUESTIONNAIRE (Phase 1)

The Calling of an Engineer: High School Students Perceptions of Engineering

This research is being conducted by Scott Compeau (Master of Applied Science, Candidate) under the supervision of Professor David Strong in the Faculty of Engineering and Applied Science at Queen’s University in Kingston, Ontario. This study has been granted clearance according to the recommended principles of Canadian ethics guidelines and Queen’s policies. The Limestone District School Board has also approved this study.

What is this study about? The purpose of this research is to understand the perceptions that grade 9 and grade 10 students, whom are enrolled in academic English, Mathematics, and Science courses, have about the engineering profession. In order to achieve the goal of understanding the phenomenon of why fewer students are interested in studying engineering, the exploratory research questions of 1) How do students perceive engineering, and 2) How do students perceive the work engineers do, must be asked.

What will this study require? If the student and parents agree to participate in this research, the student will first complete an online questionnaire (30 minutes maximum), which will be sent to the students email address. From the questionnaire, they will have the option to volunteer for a follow-up interview. I will select and contact eight students for individual interviews, based on the answers provided from the questionnaire to allow me to develop a further understanding. Interviews will be conducted at your home school, will last a maximum of one hour, and will be recorded in digital audio files.

Is participation voluntary? Your participation is completely voluntary and choosing not to participate will not result in any adverse consequences. There are no known physical, psychological, economic, or social risks associated with this study. Further, you are free to choose, without reason or consequence, to refuse to answer any questions. You may withdraw from the study at any time with no negative consequences towards your school standing. If you withdraw from the study, you may choose to have your data removed.
**What will happen to my responses?** The questionnaire and interview recording will be transcribed and then the recording will be destroyed. All electronic files will be password protected. Paper and audio data will be secured in a locked cabinet. I will maintain copies of the transcripts for a minimum of 5 years and may use the data (with names removed) in subsequent research. Confidentiality will be protected to the extent possible. None of the data will contain your name or the identity of your place of work. To protect your identity a pseudonym will replace your name on all data files and in any dissemination of findings. This research may result in publications of various types, including journal articles or other professional publications.

**What if I have concerns?** Any questions about study participation or a request to withdraw from the study may be directed to Scott Compeau at s.compeau@queensu.ca or my supervisor Professor David Strong at (613) 533-2606 or strongd@queensu.ca. Any ethical concerns about the study may be directed to the Chair of the General Research Ethics Board at (613) 533-6081 or chair.GREB@queensu.ca.
CONSENT FORM FOR PARENTS
The Calling of an Engineer: High School Students Perceptions of Engineering

Student Name (please print clearly): _______________________________________

1. I have read and retained the Letter of Information and have had any questions answered to my satisfaction.

2. I understand that I will be participating in the study called The Calling of an Engineer: High School Students Perceptions of Engineering. I understand the purpose of this research is to explore the perceptions that grade 9 and grade 10 students, whom are enrolled in academic English, Mathematics, and Science courses, have about the engineering profession. I understand that participation in this study will entail a maximum of 1.5 hours of my time involving: an online questionnaire (maximum 30 minutes), and if selected, an audio-recorded interview (maximum 60 minutes).

3. I understand that my participation in this study is voluntary and I may withdraw at any time without adverse consequences. I understand that if I withdraw from the study, I may choose to have my data removed. I understand that the data may also be published in professional journals or presented at academic conferences. I understand that every effort will be made to maintain confidentiality to the extent possible now and in the future.

4. I am aware that any questions about study participation or a request to withdraw from the study may be directed to Scott Compeau at s.compeau@queensu.ca or my supervisor Professor David Strong at (613) 533-2606 or strongd@queensu.ca. Any ethical concerns about the study may be directed to the Chair of the General Research Ethics Board at (613) 533-6081 or chair.GREB@queensu.ca.

Please sign one copy of this Consent Form and return to Scott Compeau. Retain the second copy for your records.

I have read the above statements and had any questions answered. I freely consent to participate in this study.

Participant’s Signature: _______________________ Date: ______________________

E-mail address: ___________________________________

Please check the boxes below to indicate understanding.

☐ I am granting permission for my child to provide written responses to a questionnaire.

☐ I understand that my child may be contacted in the future for an interview. At that time, I will be provided with additional information and consent forms. By granting permission for my child to take part in the initial survey, there is no obligation to participate in the possible future interview.

Guardian’s Name: _______________________ Date: ______________________

Guardian’s Signature: _______________________
B.3 Letter of Information for Students

STUDENT LETTER OF INFORMATION – INTERVIEW (Phase 2)

The Calling of an Engineer: High School Students’ Perceptions of Engineering

This research is being conducted by Scott Compeau (Master of Applied Science, Candidate) under the supervision of Professor David Strong in the Faculty of Engineering and Applied Science at Queen’s University. This study has been granted clearance according to the recommended principles of Canadian ethics guidelines, Queen’s policies, and approved by the Limestone District School Board.

What is this study about? The purpose of this research is to understand the perceptions that grade 9 and grade 10 students have about engineering profession. In order to achieve the goal of understanding the phenomenon, the exploratory research questions of 1) How do students’ perceive engineering, and 2) How do students’ perceive the work engineers do, must be asked.

What will this study require? If your parent or guardian provide consent to participate in the second phase of this research study, you may be invited to participate in a semi-structured interview that will be held to provide further insight on the students’ perceptions about engineering. Interviews will be conducted at your school at a convenient time, will last a maximum of 45 minutes, and will be recorded in digital audio files. The recordings will make sure the data is captured completely.

Is participation voluntary? Your participation is completely voluntary and there are no known physical, psychological, economic, or social risks associated with this study. Further, you are free to choose, without reason or consequence, to refuse to answer any questions. You may withdraw from the study at any time and have your data removed.

What will happen to my responses? The interview recording will be transcribed and then will be destroyed. All electronic files will be password protected. The audio data will be secured in a locked cabinet. I will maintain copies of the transcripts for a minimum of 5 years and may use the data (with names removed) in subsequent research. Confidentiality will be protected to the extent possible. To protect your identity, a pseudonym will replace your name on all data files and in any dissemination of findings. This research may result in publications of various types, including journal articles or other professional publications.

What if I have concerns? Any questions about study participation or a request to withdraw from the study may be directed to Scott Compeau at s.compeau@queensu.ca or my supervisor Professor David Strong at (613) 533-2606 or strongd@queensu.ca. Any ethical concerns about the study may be directed to the Chair of the General Research Ethics Board at (613) 533-6081 or chair.GREB@queensu.ca.
INTERVIEW CONSENT FORM FOR PARENTS – INTERVIEW (Phase 2)

The Calling of an Engineer: High School Students’ Perceptions of Engineering

Student’s Name (please print clearly): ________________________________________

1. I have read the Letter of Information and have had any questions answered to my satisfaction.

2. I understand that I will be participating in the study called The Calling of an Engineer: High School Students’ Perceptions of Engineering. I understand the purpose of this research is to explore the perceptions that grade 9 and grade 10 students’ have about the engineering profession. I understand that participation will entail an audio-recorded interview (maximum 45 minutes).

3. I understand that my participation in this study is voluntary and I may withdraw at any time without adverse consequences. I understand that if I withdraw from the study, I may choose to have my data removed. I understand that the data may also be published in professional journals or presented at academic conferences. I understand that every effort will be made to maintain confidentiality to the extent possible now and in the future.

4. I am aware that any questions about study participation or a request to withdraw from the study may be directed to Scott Compeau at s.compeau@queensu.ca or my supervisor Professor David Strong at (613) 533-2606 or strongd@queensu.ca. Any ethical concerns about the study may be directed to the Chair of the General Research Ethics Board at (613) 533-6081 or chair.GREB@queensu.ca.

Please sign one copy of this Consent Form and return to your teacher.
Retain the second copy for your records.

I have read the above statements and had any questions answered. I freely consent to participate in this study.

Participant’s Signature: _______________________ Date: ________________________

Parent or Guardian: Please check the boxes below to indicate understanding.

☐ I am aware that the interview will be audio recorded for research purposes.
☐ I am granting permission for my child to provide responses to a semi-structured interview. I would prefer the interview be conducted in;

Guardian’s Name: _________________________ Date: _________________________

Guardian’s Signature: _________________________

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Appendix C

Data Collection Instruments

C.1 Phase 1 Questionnaire

C.2 Phase 2 Interview Guide

C.3 Student/Parent Letter of Information – Phase 2 Interview
## C.1 Phase 1 Questionnaire

<table>
<thead>
<tr>
<th>Question</th>
<th>Response Selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.  What grade are you in?</td>
<td>o  Grade 9&lt;br&gt;o  Grade 10</td>
</tr>
<tr>
<td>2.  Which high school do you attend?</td>
<td>Open</td>
</tr>
<tr>
<td>3.  Which gender do you associate yourself with?</td>
<td>o  Male&lt;br&gt;o  Female&lt;br&gt;o  Transgender</td>
</tr>
<tr>
<td>4.  Select all of the courses that you are currently enrolled in.</td>
<td>o  Academic English&lt;br&gt;o  Academic English&lt;br&gt;o  Academic English</td>
</tr>
<tr>
<td>5.  When you graduate from high school, are you planning on attending university?</td>
<td>o  Definitely&lt;br&gt;o  Probably&lt;br&gt;o  Probably Not&lt;br&gt;o  Definitely Not</td>
</tr>
<tr>
<td>6.  Are you considering studying engineering at university or college?</td>
<td>o  Definitely&lt;br&gt;o  Probably&lt;br&gt;o  Probably Not&lt;br&gt;o  Definitely Not</td>
</tr>
<tr>
<td>7.  On the following scale, with one being you don’t know at all and ten being you know very well what a person in this field does on a day-to-day, please rate your knowledge of each profession.</td>
<td>Not Well ------------------------------- Very Well&lt;br&gt;1 ---------------------------- 10</td>
</tr>
<tr>
<td>Teacher, Lawyer, Doctor, Engineer, Scientist, Architect, Designer</td>
<td></td>
</tr>
<tr>
<td>8.  Please indicate how important each of the following are for you in considering which career path to choose.</td>
<td>o  Extremely important&lt;br&gt;o  Very important&lt;br&gt;o  Not that important&lt;br&gt;o  Not important at all</td>
</tr>
<tr>
<td>Salary, Recognition, Interesting work, Challenging work, Work that makes a difference or is meaningful, Availability of jobs in the field, Prestigious field.</td>
<td></td>
</tr>
<tr>
<td>9.  What are the first words, phrases or images that come to mind when you think about engineering?</td>
<td>Open</td>
</tr>
<tr>
<td>10. In your opinion, what does a professional engineer do? Can you give an example of the work they do?</td>
<td>Open</td>
</tr>
</tbody>
</table>
11. For each of the following, please indicate how well you think it describes engineers or the field of engineering.

- Creative, the work is rewarding, fun, gets results, hardworking, have a positive effect on people’s lives, inventors, leaders, nerdy, original thinkers, problem solvers, well paid, must be smart to get into this field, must be good at math and science, builds constructs or makes things, designs draws or plans things, sits at a desk all day, mostly men, mostly white, well respected, requires too many years to get a degree, entrepreneurial, boring, often works outdoors.

   - Very Well
   - Somewhat well
   - Not very well
   - Not well at all

12. What subjects do you think are essential to take in high school to become an engineer?

   - Business
   - Science
   - International Languages
   - English
   - Math
   - Tech Ed
   - Health and PE
   - Computer Studies
   - Other

13. What are the first words, phrases, or images that come to mind when asked to describe a designer and the work they do?

14. Tell me about the ways designers are similar and/or different from engineers.

15. Do you know any engineers? If yes, list how you know them?

16. Selected all of the images that you think represent the work that engineers do.

   - Improve machines, supervise construction, set up factories, construct buildings, drive machines, arrange flowers, read about interventions, design ways to clean water, work as a team, make pizza, install wiring, sell food, repair cars, design things, clean teeth, teach children.

17. Are you interested in being contact for a follow up interview?

   - Yes
   - No

If yes, please enter your name
C.2 Phase 2 - Interview Guide

Introduction: Researcher introduces himself.

I am conducting a research study to investigate the perceptions of engineering that grade 9 and 10 students have. I am interested in learning about your perceptions and hearing what you have to say about the field of engineering, the work engineers do, and the qualities/characteristics of an engineer. I want you to tell me about your experiences, if any, with engineering and provide your honest answers to the best of your abilities.

I am conducting interviews with males and females in both grade 9 and grade 10 across five different high schools. The results of this research will help me develop a further understanding of the emerging perceptions that were obtained from the questionnaire in part 1 of the study.

Ask participants: Do you have any questions about the purpose of the research?

Questions to students

There are twelve questions to this semi-structured interview, which will take a maximum of 60 minutes. The questions in the interview will be similar in content to the questionnaire but will allow you the opportunity to express yourself orally and elaborate on the answers you previously provided. The interview will follow a semi-structured format in that the standard questions will be asked, however, additional related questions may be asked if the opportunity presents itself and if the researcher decides they are necessary. Before we begin, let me remind you of two notes in the Letter of Consent that you and your parents signed:

- Your identity will remain confidential - when I write about this interview we will not use your real name, nor will we use your name when I tell anyone what you said.
- Whatever you tell us in the interview will not affect your school assessments.

Let us begin the interview.

Researcher’s closing script: Thank you for participating in this research.
### C.3 Phase 2 - Interview Questions

<table>
<thead>
<tr>
<th>Interview Question</th>
<th>Purpose of Question</th>
<th>Purpose of Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What are the first words, phrases or images that come to mind when you think about engineering?</td>
<td>Determine the participants’ knowledge of the engineering profession.</td>
<td>DIRECT Question</td>
</tr>
<tr>
<td>2. What does a professional engineer do? Can you give an example of the work they do?</td>
<td>More focused question on what engineers do.</td>
<td>DIRECT Question</td>
</tr>
<tr>
<td>3. What characteristic or qualities are necessary to become a successful engineer?</td>
<td>Determine what participants think is involved in becoming an engineer.</td>
<td>Triangulation question</td>
</tr>
<tr>
<td>4. What factors or motivators would influence someone to want to pursue engineering?</td>
<td>Determine what the participants think would motivate someone to become an engineer.</td>
<td>Triangulation question</td>
</tr>
<tr>
<td>5. What courses do you think are essential to take in high school to become an engineer?</td>
<td>Determine what is required in order to succeed in engineering undergraduate programs and the profession.</td>
<td>Triangulation question</td>
</tr>
<tr>
<td>6. What comes to mind if I ask you to describe a designer and the work that they do? Tell me about</td>
<td>Determine what participants think about designers, what does</td>
<td>DIRECT Question</td>
</tr>
<tr>
<td>the ways that designers differ from engineers.</td>
<td>the word design encompass?</td>
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<tr>
<td>7. What comes to mind if I ask you to describe a scientist and the work that they do? Tell me about the ways that scientists differ from engineers.</td>
<td>Determine what participants think about scientists, what does the word science encompass?</td>
<td></td>
</tr>
</tbody>
</table>
| **Definition of Engineering:**  
The professional activity of creating artefacts and systems to meet people’s material needs, with design as the central creative process, scientific knowledge and economic considerations as its essential inputs, and public safety as its overriding responsibility | New Question | 
| 8. Tell me about your instant reaction after reading the definition. Is there any component of the definition that is surprising or unexpected? | New Question | 
| **What does a professional engineer do?**  
Professional engineers design products, processes and systems that protect the environment, and/or enhance the quality of life, health, safety and well-being of Canadians. They also manage world- | New Question |
leading companies at the forefront of emerging technologies.

9. Tell me about your instant reaction after reading the definition. Is there any component of the definition that is surprising or unexpected?

10. How/Where do you think you formed your understanding about engineering?

11. On the questionnaire you answered “______” when asked if you were considering engineering as a career option. Has this discussion about engineering and reading the definitions change this answer or is it the same?

12. Do you know any engineers?