# HIGH SCHOOL STUDENTS' VIEWS ON ENGINEERS CANADA'S DEFINITION OF PROFESSIONAL ENGINEERING WORK

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***Abstract*** *- The breadth of the engineering profession is illustrated by Engineers Canada's (EC) recognition of over 120 accredited engineering programs across the country. Arguably, the work of a professional engineer spans over an even larger scope. However, synthesizing a description of engineering work that encompasses all aspects of the profession is extremely difficult. Applicants to engineering programs in Canadian universities require high standing in specific course pre-requisites. In order to make an informed decision with regard to engineering as a possible career path, it is critical that students clearly understand the engineering profession. The purpose of this paper is to describe how Grade 9/10 students' perceptions of engineering work compares to EC's description, based on the outcomes of a research study involving a questionnaire and interviews. The findings show that the emerging categories from these students' descriptions of engineering work that aligns with EC's description, involves design (42.3%) and helping people or the environment (16.5%).*

**Keywords:** High school, student's perceptions, K-12, Engineers Canada, engineering education.

## 1.0 INTRODUCTION

In 2015, Engineers Canada (EC) reported that the Canadian Engineering Labour Market predictions indicate that the projected availability of engineers for all 14 disciplines recognized by EC is higher than the predicted number of jobs through to 2025 [1]. In the same report, the large and growing demand to replace retiring engineers as they exit the workforce over the next decade is also highlighted [1]. These somewhat contradictory statements might suggest that there is an imbalance of engineers working in the profession. According to a 2015 report by the Ontario Society of Professional Engineers (OSPE), only 29.7% of individuals with engineering degrees work as engineers or engineering managers in Ontario [2]. This raises a question of whether the ~30% of degreed engineers working in engineering roles are by choice or by availability of suitable employment. However, assuming the breadth of employment options for engineering graduates is a factor, it provides one explanation as to why EC reported a demand for engineers through 2025.

One possible strategy for increasing the pool of high-quality engineering graduates to meet the demand for the profession is possible during the early high school years, before students make course choices that may influence career options. Increasing the level of knowledge that high school students have about engineering may contribute to more accurate perceptions about the profession, hence providing them with the ability to make an informed choice about an engineering career.

According to EC [3], the description of what professional engineers do is, "design products, processes and systems that protect the environment, and/or enhance the quality of life, health, safety and well-being of the public. They also manage world-leading companies at the forefront of emerging technologies". With this definition at the core of the engineering profession in Canada, knowing how the high school student body describes engineering work, and how it compares to EC's description is important to determine if and in what form of response, may be required to ensure students can make informed decisions in considering engineering as a post-secondary program.

Previous research has suggested that Grade 7 students have very little knowledge of the engineering profession [4], and it can be hypothesized that this trend continues into the early high school years. The research encompassed in this paper highlights how Grades 9 and 10 students' perceive the work of engineers based on the components of EC's description. The data can be used to inform both researchers and practitioners (such as teachers, engineering outreach organizations, and policy makers) about potential missing links between students' perceptions of engineering work and EC's description.

## 2.0 METHODS

In order to fully explore this issue, it was important to determine not only what students think about engineering work, but the reasoning behind their thinking. Data of this nature is best collected through a combination of methods. By focusing on combining distinct elements from pure methodological strategies and mixing the measurement,

design, and analysis components of quantitative and qualitative inquiry strategies, a methodology emerges that is specific to the research questions. In this study, a multiple methods approach (a questionnaire and interviews) was chosen, and analysis included a combination of content analysis and statistical analysis. In addition, a constructivist methodology framed the data collection and analysis, as an interpretivist approach is used to 'understand and to portray the participants perceptions and understandings of the particular situation or event' [5, p. 38].

The participants in the study were recruited from 20 different classes across five high schools ranging in size from 400 to 800 students in both urban and rural settings, and from a range of socio-economic status, within the academic year 2014-2015. The participant selection at each school was 'purposeful' [5, p. 40] in that a criterion-based sampling strategy was applied. The inclusion criteria was that all participants must be enrolled in Grade 9 or 10 academic level English, Math, and Science courses. The justification behind this sampling strategy was to describe students' perceptions who demonstrate the required academic capabilities for potentially applying to study engineering. Although the demographic mixture is increased by sampling students across five schools and it allows for a diverse cross-section of the student population, it is important to acknowledge that by using a criterion-based sampling strategy, it is unknown if the sample population is representative of the entire school.

The first of the multiple methods used for data collection was an online questionnaire that was blended and modified to include questions from two previous studies by the American National Academy of Engineering (NAE) [6] [7], as well as three other studies used to determine people's perceptions of engineering work [8] [9]. The questionnaire was designed to incorporate both closed (quantitative) and open-ended (qualitative) questions. Close-ended data was analyzed using SPSS statistical analysis software, while open-ended data was transcribed into Microsoft Word for coding and analysis. Once transcribed, descriptive statistics were used to summarize the findings. To delve deeper into the preconceived notions these students had about engineering work and obtain a rich understanding of their level of knowledge, semi-structured interviews were conducted on a small subset of the survey respondents. The interviews consisted of similar questions from the questionnaire as a form of triangulation, and to increase the study's trustworthiness.

## 3.0 RESULTS

The findings in this paper first illustrate the breakdown of participants into four separate groups to help understand the breakdown of the sample population and to help aid in analysis. Secondly, the paper discusses the themes that emerged from the study on students' perceptions of engineering work and as to how they compare to EC's description of what engineer's do. Based on EC's description, the components are; design products, processes, and systems; protecting the environment; helping people; public safety; and managing world-leading companies.

### 3.1 Description of participants

Out of a possible 862 students, a total of 97 completed the online questionnaire. The crosstab demographic breakdown for the first two groups (Grade and Gender) is shown in Table 1.

*Table 1: Demographic breakdown of participants*

| | **Male** | **Female** |
|---|---|---|
| **Grade 9** | 34% | 38% |
| **Grade 10** | 10% | 18% |

In addition to the demographic breakdown, the participants were also grouped by school, including the socio-economic status (SES) ranking between the schools which was determined by using catchment area of each school, shown in Table 2. The final group used to help understand the sample population was the students' self-identified relationship to an engineer (Table 3). Based on their responses, the students were grouped into four different categories. The 'Yes – No Connection' category was derived from students' responses that mentioned famous engineers that they did not personally know.

*Table 2: School breakdown of participants*

| **School** | **% of participants** | **SES Ranking** | **Classification** |
|---|---|---|---|
| **A** | 26 | 1st | Urban |
| **B** | 8 | 2nd | Urban |
| **C** | 33 | 3rd | Urban |
| **D** | 22 | 4th | Rural |
| **E** | 11 | 5th | Urban |

*Table 3: Participant relationship to an engineer breakdown*

| **Relation to an engineer?** | **% of students** |
|---|---|
| Yes - Family member | 29 |
| Yes - Personal connection | 20 |
| Yes - No connection | 7 |
| No relationship | 44 |

These students' perceptions of engineering work were analyzed to determine if any significant differences existed between the four groups. However, it is important to note

that investigating the differences was not one of the specific research questions of this study and therefore serves the purpose of providing insight that could be used for future research. To test for significant differences throughout the questionnaire, a t-test was conducted to compare mean scores between grades and genders, while an analysis of variance (ANOVA) with a post-hoc test was run to compare mean scores between schools and knowing an engineer. For the questions that looked at the frequency of responses as oppose to the mean score, a Pearson Chi-Squared test was conducted to determine if any significant differences existed between the four groups.

## 3.2 Describing engineering work – closed questions

To provide insight towards how these students view engineers, they were asked to select, using a four-point Likert scale (1 = Not well at all and 4 = Very well), how well a list of 24 attributes describes engineers. The mean score for the 3 attributes that are mentioned and/or related to EC's description are presented in Table 4.

*Table 4: Attributes that describe engineering work*

| Attribute | Design, draw, plan | Positive impact on lives | Leader |
|---|---|---|---|
| Not well at all (1) | 1 | 0 | 3 |
| Not well (2) | 2 | 9 | 23 |
| Somewhat well (3) | 43 | 39 | 45 |
| Very well (4) | 51 | 49 | 26 |
| Mean score | 3.48 | 3.41 | 2.97 |
| Stand. Dev | 0.60 | 0.66 | 0.80 |

The results indicated that over 50% of the students in this study perceived that the 'design, draw, and plan' and 'positive impact on lives' attributes describe engineers very well. Testing for significant differences ($p <= 0.05$) between the four groups (gender, grade, school, and relationship to an engineer) did not indicate any differences for these 3 attributes. A second question asked students to select which of a list of 16 job descriptions accurately describe the work of an engineer. The number of participants who said 'Yes' (meaning the description describes typical engineering work) for the 3 descriptions that are mentioned and/or related to EC's description is presented in Table 5.

*Table 5: Job descriptions describing engineering work*

| Job description | Typical engineering activity? | # of students who said 'Yes' | % Correct |
|---|---|---|---|
| Improves machines | Yes | 96 | 95.6 |
| Design things | Yes | 91 | 90.7 |
| Design ways to clean water | Yes | 77 | 77.3 |

From on the results, over 90% the students in this study selected 'Yes', which correctly identified that engineers typically improve machines and design things, while 77% selected 'Yes', which correctly identified that engineers design ways to clean water. To measure if any significant differences existed between the four groups, the participants' responses for each job description were scored as correct or incorrect. For example, if a student selected 'Yes' for the 'improves machines' job description which was classified as typical engineering work, it was coded as one point, otherwise it was zero. Using the total 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 than the Grade 9's to correctly identify 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 and post-hoc analysis for comparing schools indicated that the participants at School A were more likely to correctly identify that engineers 'design things' and 'design ways to clean water' than the participants at School D ($p <= 0.05$). Gender and the relationship to an engineer did not have any significant differences in these response areas.

## 3.3 Describing engineering work – open questions

One of the open-ended questions from both the questionnaire and the interviews asked the participants to describe the first words, phrases, or images that come when thinking about the work of an engineer. Using inductive analysis, the individual responses were coded into reoccurring words, and then grouped together into categories. The categories, although qualitative in nature, were also used for quantitative purposes to record the number of students (frequency) who provided a word that fit within the specific category. The frequency of participants who mentioned each category from the online questionnaire are presented in Table 6.

*Table 6: Categories describing the work engineers do*

| Category | Frequency of responses |
|---|---|
| Central Creative Process - Mental | 41 |
| Central Creative Process - Physical | 28 |
| Engineering Products | 23 |
| Helping People or the World | 16 |

The 'Central Creative Process – Mental' category (which consists of the codes Design, Create, Innovate, Improve), has the highest frequency of responses at 41 participants (42.3%), and 'Helping People or the World' had 16 participants (16.5%). Within the student's responses, the depth and detail describing the work of a professional engineer ranged from one single idea or word, to a complete sentence encompassing multiple ideas. Examples of student responses that mention and/or related to EC's description are provided in **Error! Reference ource not found.**7.

*Table 7: Responses describing engineering work*

| Category | Participant quote |
|---|---|
| **Central Creative Process (Mental)** | "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 |
| **Central Creative Process (Physical)** | "I think a professional engineer would build stuff people always use. They would be part of building computers and vehicles. " – Conrad |
| **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" – Jenna |
| **Helping People or the world** | "Design and build things that would 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 |

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 the mental components of the 'Central Creative Process' category as well as 'Helping People of the World' ($p <= 0.05$). When comparing schools, the chi-squared and post-hoc analysis indicated that both the 'Central Creative Process' categories contained differences. Students at School A were significantly more likely to mention the category 'Central Creative Process' compared to students at School E ($p <= 0.05$).

Within many of the participants' responses for describing the work of an engineer, a number of ideas 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 engineers do *"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 really 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.

In addressing the issue of reliability from a positivist viewpoint, and dependability from a naturalistic viewpoint, the questionnaire incorporated several opportunities to describe engineering work. Focusing on the concept of design will provide insight into the dependability of these students' responses. The open-ended responses describing engineering work included 41 participants that mentioned design. Of that, 29 participants (70%) indicated that 'design, draws, and plans things' describes engineering work 'very well', with another 8 participants (30%) selecting 'somewhat well'. Additionally, all 41 participants correctly identified that engineers 'design things'. The results from these examples demonstrate a high level of dependability from students' responses.

## 3.4 Student's thoughts about EC's description

EC's description of professional engineering work was held in high regard by the interview participants as 45% (5 of 11) of the participants mentioned that it aligns with their original thoughts about what engineers do. Tara was supportive of this definition by saying; "*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. 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. Definitely protecting the environment is what I think of an engineer. So having that in there makes me feel happy."*

The emphasis that EC placed on engineers having a role to play in protecting the environment was a surprise to Rylan when he mentioned; "*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*". In addition to the environmental aspect, the idea that engineering work enhances the quality of life was a surprise to a few students such as 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.*" The final surprising component was that engineers can manage world leading companies. Depending on the students' perception, 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.*"

One student, Miranda, appeared to struggle accepting EC's 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 reaction after reading the description of what a professional engineer 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."*

As discussed earlier, one form of data triangulation used in this study was to ask some of the same questions in the questionnaire and in the interview. By including this form of triangulation, it increases the trustworthiness of the study [5]. The data from the questionnaire and interview were analyzed separately which allowed for themes to emerge and then be compared. One example of the responses from the questionnaire and interview are presented in Table 8 and support how the triangulated responses increased the trustworthiness.

*Table 8: Example of triangulated response*

| Person | Questionnaire | Interview |
|---|---|---|
| **Miranda** | A professional engineer is someone who creates, designs, or fixes something (most likely technology) to make life easier or more interesting for people. | Design and build things that work to help people in today's society; they work on something – they have an idea, plan it out and then test it, if it works then they build whatever it is they're planning. |

## 4.0 DISCUSSION

Comparing the results from this study to the components of EC's description of engineering work, these students mentioned the components of design, protecting the environment, and helping people.

### 4.1 Engineering work involves design

When the students described the work engineers do, the highest percentage of them used the words 'design', 'create', or 'innovation'. This suggests that these students have an understanding of the mental aspects of engineering. This was supported by the high mean score for 'Design, draw, and plan' attribute (Table 4) and the high percentages of students who correctly identified 'design' from a list of 16 job descriptions (Table 5). In addition to the closed responses, the highest frequency of coded responses in the open questions of the questionnaire also included the mental aspects (Table 6). Although this category had the highest frequency of responses, it is important to note that it was only mentioned by 42.3% of the participants. Using the words 'design' or 'create' to describe engineering work in this study was also a major theme that emerged from the two previous studies conducted by the National Academy of Engineering [7] [6], and from Montfort's study with secondary students [9]. However, the difference between the students in Montfort's study and those in this current study was that the participants in Montfort's had received a formal engineering education intervention.

This result may have significance towards EC as 'design' is one of the major components within the description of engineering work and less than half of this student sample population were able to make this link.

### 4.2 Engineers help's people and/or the environment

Some students in this study (16.5%) described engineers and the impact they have on people's lives, or the environment. This suggests that those students have an understanding of the connection between engineers and society. The role of an engineer and helping the community was reported in Montfort's study [9], but within NAE's study [6], engineers were not recognized as contributing to the public's quality of life and the environment. Within EC's description of engineering work [3], this relationship between engineers and helping people and/or the environment is explicitly mentioned and is important to the profession. The significance of this result is that only 16.5% of students within this study are aware of this aspect

of engineering. The corresponding high percentage of students who are unable to make this link to engineering work may have inaccurate perceptions of the profession.

### 4.3 Implication and recommendations

This research study was useful in learning about how these students in Grade 9 and 10, from one school board in Ontario, view the work of an engineer as to how it relates to EC's description. The results and discussion may suggest implications and recommendations for both educators and researchers. One implication for educators could be to use the methods and/or results described in this paper to openly discuss engineering with high school students. The use of EC's description will not only increase students' exposure to the engineering profession, but can also be used to discuss how their individual perceptions is similar and/or different to EC's description. A possible area for future research is with Engineers Canada. As a governing body, it is important to promote the profession to the general public, and especially pre-university students. This research study provided some preliminary evidence that Grade 9 and 10 students are unaware about several aspects of engineering work that were used in EC's description.

There are two future research questions that may be worth exploring; 1) does the current description of engineering work provided by EC sufficiently represent the work of practicing professional engineers in Canada; and 2) would multiple descriptions of engineering using age appropriate language to specifically target different audiences help provide clarity about the profession?

## 5.0 CONCLUSION

EC's description of what professional engineer's do can be separated into the components of designing; protecting the environment; helping people; public safety; and managing world-leading companies [3]. After the interview students read EC's description, their overall reflection was positive, as the description potentially helped clarify some of their individual thoughts. However, based on the survey results, which did not include the EC description, most of these students' perceptions of engineering work did not mention the description's components related to public safety, managing companies, and only to a very modest extent, helping people and protecting the environment. In fact, it can also be argued that since less than half the participants mentioned design, this component of EC's description was also notably under-represented. Since these components are sufficiently important to the engineering profession to be specifically highlighted within EC's description of engineering work, they should arguably be part of the conversation about engineering in the early high school years, if not even before that in primary grades.

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