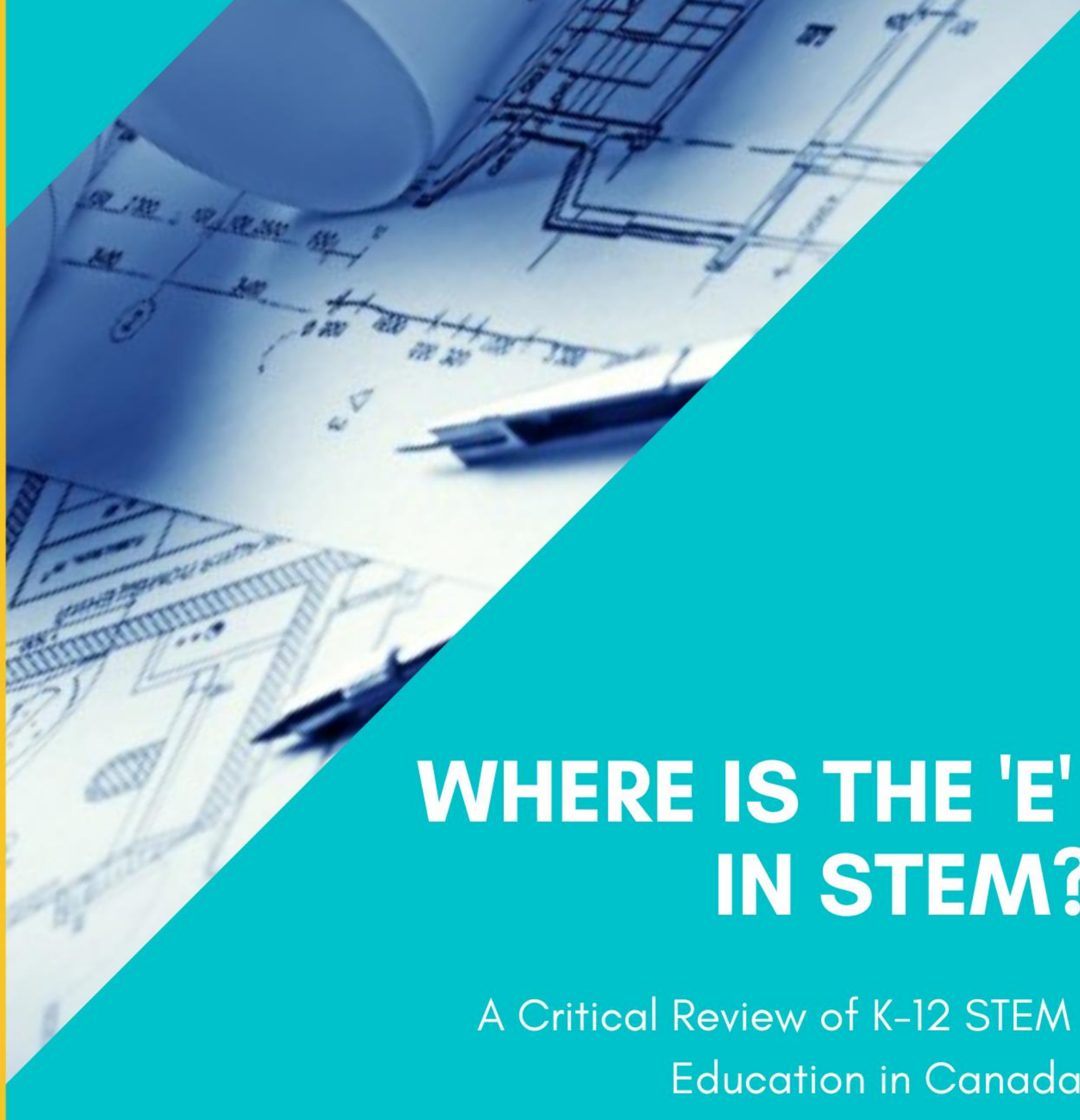

WHERE IS THE 'E' IN STEM?

A Critical Review of K-12 STEM Education in Canada

Prepared for:
Engineers Canada

MQO
RESEARCH RECHERCHE

Executive Summary

Science, technology, engineering, and mathematics (STEM) teaching in the Canadian K-12 school system has increasingly become a priority for Canada's federal and provincial governments. Despite this the literature shows that Canada is lagging behind the top five innovator countries in STEM innovation due to an outbalance of job creation in STEM fields and available qualified workers to work in these jobs [1]. Several authors attribute this outbalance to the inability of the Canadian school system to interest their students in STEM-related subjects at an early age [2, 3]. Further, despite the widespread discussion of STEM in the literature, many studies fail to address each subject of the STEM acronym individually. When looking specifically at the 'E' (Engineering), there is a lack of research on how it is incorporated into the Canadian K-12 curriculum.

The purpose of this report is to examine current **engineering-related K-12 initiatives** throughout Canada and ways in which STEM education has incorporated engineering concepts and to provide strategic direction to move K-12 engagement in engineering forward.

ENGINEERING IN K-12 IN CANADA

The presence of engineering as part of STEM in the classroom varies widely. Overall, engineering appears to be under-represented or unidentified in the K-12 classroom. This is due, in part, to a lack of explicit inclusion of engineering as a learning outcome/goal early in the Canadian curriculum; and the language used to describe engineering exercises and concepts in the classroom. The absence of the word *engineering* in "STEM" within the K-12 space is a key takeaway. Our research suggests that educators and organizers are facilitating a breadth of engineering-related activities in the K-12 space, but it is not labeled as such and is obscured by framing these activities broadly as "STEM".

To better understand what the K-12 engineering ecosystem in Canada looks like, an initial map of organizations promoting engineering in the K-12 space was prepared and can be found here: K-12 Engineering Ecosystem Map Canada. The organizations identified in the mapping exercise represent organizations in Canada that are promoting engineering in K-12 Canada in a variety of ways including camps, professional development for teachers, resources for teachers, classroom visits, mentorship, summer employment programs, tournaments and competitions, funding, networking, community events, and gender-based initiatives.

BARRIERS AND BEST PRACTICES

Although there are a variety of ways that organizations are promoting engineering among the K-12 age group, most acknowledge (or are trying to address) similar barriers. Some of the most common barriers identified for students pursuing engineering or engineering-related courses include perceptions or misconceptions about engineering, socioeconomic status, and/or identifying as part of a minority group. Research suggests three of the best practices in implementing engineering programming for K-12 include:

1. Mentorship and Role Models
2. Providing Engineering & STEM Programming within a Community Context
3. Getting Started Early - Pre-K Engagement

MEASURING PROGRESS AND EVALUATING WHAT WORKS

In attempting to identify best practices for engineering programming and initiatives for K-12, it was noted that very little objective data is available to gauge the success of different types of programming. In addition, provincial data was not available at the student level to benchmark the impact of differences in curriculum and available programming province-to-province. The lack of consistent data collection and availability makes it difficult to establish and identify best practices to support K-12 goals, evaluate engagement in engineering or track the potential to meet future labour market needs.

Although the best practice research provided several recommendations that are valuable to the implementation of specific programs, it is recommended that strategic priority be given to five key goals for the most significant impact in boosting engineering promotion in K-12 across Canada.

1. **FOCUS ON LANGUAGE:** Promote the increased use of the word engineering in the classroom and increase educator confidence by establishing and promoting a simple to understand shared definition and messaging.

2. **ADVOCATE FOR THE EXPLICIT INCLUSION OF ENGINEERING IN CURRICULUM ACROSS CANADA:** Advocate for engineering to be explicitly identified in K-12 learning objectives or outcomes in all provincial curricula. This essential move will help further encourage educators to talk about engineering more directly, using the right language in the classroom.

3. **ESTABLISH A MECHANISM TO GATHER AND UTILIZE SHARED DATA:** Address short-term gaps in data by conducting a survey with post-secondary students currently pursuing engineering. Advocate for access to student-level enrollment data for K-12 students, identify shared performance indicators and encourage data-sharing among organizations.

4. **INCREASE OPPORTUNITIES FOR COMMUNICATION AND COLLABORATION:** Increased collaboration and communication opportunities would bolster impact by allowing organizations to share lessons learned and maximize resources by working together. This could be achieved by adopting a collective impact model.

5. **EXPLORE THE ADOPTION OF A COLLECTIVE IMPACT MODEL TO FACILITATE CHANGE:** Explore the benefit of utilizing a collective impact model as a proven approach to address the above goals by promoting structured collaboration and systems-level change.

This report provides a first look at how the ‘E’ (Engineering) is represented in STEM education and the landscape of K-12 engineering initiatives in Canada. The recommendations presented here represent strategic direction to focus efforts on the promotion of engineering in the K-12 space to increase the number of Canadians choosing to pursue a career path in engineering.

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INTRODUCTION

Science, technology, engineering, and mathematics (STEM) teaching in the Canadian K-12 school system has increasingly become a priority for Canada's federal and provincial governments.

Despite the widespread discussion of STEM in the literature, many studies fail to address each subject of the STEM acronym individually. When looking specifically at the E (Engineering), there is a lack of research on how it is incorporated into the Canadian K-12 curriculum.

1.0. Introduction

Science, technology, engineering, and mathematics (STEM) teaching in the Canadian K-12 school system has increasingly become a priority for Canada's federal and provincial governments. Despite this, the literature shows that Canada is lagging behind the top five innovator countries in STEM innovation due to an outbalance of job creation in STEM fields and available qualified workers to work in these jobs [1]. Several authors attribute this outbalance to the inability of the Canadian school system to interest their students in STEM-related subjects at an early age [2, 3]. Further, despite the widespread discussion of STEM in the literature, many studies fail to address each subject of the STEM acronym individually. When looking specifically at the 'E' (Engineering), there is a lack of research on how it is incorporated into the Canadian K-12 curriculum.

Although the Government of Canada has introduced a variety of federal funding initiatives to encourage the participation of young Canadians in STEM-related fields, there appears to be a lack of funding for research that examines engineering-related initiatives. The purpose of this report is to examine current **engineering-related K-12 initiatives** throughout Canada and how STEM education has incorporated engineering concepts. The report will also provide recommendations on educational policies, programs, and practices that could permit meaningful inclusion of engineering-related K–12 curriculum in Canada. The examination of engineering-related initiatives for youth is important because they are essential to developing a workforce with the knowledge and skills to address technical engineering issues in the future.

1.1. Methodology

A review of engineering-related initiatives for youth in Canada was conducted through five complementary approaches.

1. Literature & Best Practices Review
2. Jurisdictional Scan
3. Online Survey & Key-Informant Interviews
4. Analysis of Enrollment Data
5. Conclusions and Recommendations

Step 1: Literature Review & Best Practices

A comprehensive literature review was conducted to gain an understanding of current research findings on engineering-related K-12 initiatives; specifically, what policies and best practices should be implemented to ensure quality K-12 engineering education in Canada. This review included general background research on engineering-related K-12 initiatives as well as best practice research through a review of current scientific publications that include research on STEM or engineering-related programming for youth.

Step 2: Jurisdictional Scan

A jurisdictional scan is a multi-approach review of what practices and policies exist across jurisdictions. MQO conducted a jurisdictional scan to gain an understanding of how engineering is currently represented in the Canadian K-12 system and what Non-Governmental Organizations (NGOs) and different education boards are doing to incorporate engineering in STEM learning. The scan was conducted through a comprehensive search of publicly available data from provincial Department of Education websites and other related sources. It focused on the current implementation of engineering programs within the K-12 education system and what initiatives are being offered by programs across the country. A summary of the jurisdictional scan is provided in Appendix A.

Step 3: Online Survey & Key-Informant Interviews

To supplement data from the literature review and jurisdictional scan, an open link survey was designed and distributed to Canadian organizations that support engineering initiatives for youth. The survey was designed in collaboration with Engineers Canada. The survey sample was based on a snowball sampling model and MQO worked to reach out to associations through social networks and sourcing contacts to encourage participation. At the time of writing, twenty organizations responded to the survey. A copy of the survey questionnaire can be found in Appendix B and survey highlights are presented in Appendix C.

Key-informant interviews are designed to gather in-depth information, including opinions, explanations, and examples concerning industry concerns, support needed current state and expectations. MQO conducted eight key-informant interviews with education leaders, industry associations, and NGO representatives. These interviews provided rich data to supplement the literature review and jurisdictional scan. A copy of the key informant interview guide can be found in Appendix D. The inclusion of key-informant interviews also allowed for an assessment of the reliability of specific findings by comparing results of various methodologies (e.g., secondary research, online survey, key-informant interviews).

Step 4: Analysis of Enrollment Data

Analysis of enrollment data and necessary prerequisites for admission to post-secondary programs was attempted through an examination of data requested from provincial Departments of Education and other related sources. The analysis intended to focus on identifying the demands for continual engineering education in Canada.

Step 5: Conclusions and Recommendations

A gap analysis integrating the findings from the various research approaches examining what is happening now in Canada to promote engineering in the K-12 space against research-based recommendations from the best practice and literature review. The resulting summary outlined key recommendations and areas of focus for K-12 engineering organizations to encourage interest and engagement in the 'E' in STEM among Canadian youth, as well as recommendations on educational policies, programs, and practices that could permit meaningful inclusion of engineering-related K–12 curriculum in Canada.

LITERATURE REVIEW & BEST PRACTICES

Current research on incorporating engineering into K-12 learning addresses barriers and best practices in programming. Common barriers include language, perceptions of engineering and lack of access for marginalized groups. Aspects of programming that have been found to be effective at increasing interest in engineering among youth include mentorship, pre-K engagement and delivering programming within a community context.

2.0. Literature Review & Best Practices

Early engagement in STEM-related subjects has been correlated with an increased likelihood of pursuing a university degree in STEM-related fields. Positive engagement appears to have an even greater effect; researchers in Ontario found a strong association between high grades in STEM-related subjects in high school and a student's likelihood to pursue a dSTEM degree and/or take non-mandatory STEM courses [3]. In short, being successful in STEM leads to continued engagement in the field.

However, the literature points to multiple psychosocial barriers that prevent positive youth engagement in engineering. These include:

1. Language Around Engineering
2. Public and Student Perceptions of Engineering
3. Educator Perceptions of Engineering
4. Socioeconomic Status and Minority Groups

2.1. Barriers to Incorporating Engineering in the K-12 Education System

LANGUAGE AROUND ENGINEERING

Engineering is defined as *"the application of knowledge to solve a problem or fulfill a need"* [4]. While teachers are regularly required to teach the scientific method, they report being less familiar with the engineering design process (EDP) [5], which is distinct in its focus on criteria and constraints to design solutions to problems. In general, within the K-12 system engineering is partially embedded into the curriculum through the use of engineering tools (i.e., science, math) and end-of-unit projects. However, teachers may be lacking the appropriate language to refer to such activities as engineering.

The literature suggests that it is important to provide students with an explanation of the distinctions between the fields of engineering and science [4]. Notably, children as young as five can simultaneously engage in multiple stages of an engineering design process while also comprehending the differences between scientists and engineers [7]. To achieve this, teachers may need additional training in incorporating engineering concepts into their current curriculums. The concept of language around engineering was discussed with a key-informant interview participant who emphasized, "*it can be easy to put the 'E' in STEM but forget to say it*."

"It can be easy to put the 'E' in STEM but forget to say it."

Quote from key-informant interviews

The US Department of Education provides instructional practices to integrate language while teaching engineering methods [6]. These practices provide students with opportunities to label and actively engage with engineering-related tasks, and include:

- *"Asking questions and defining problems;*
- *Developing and using models;*
- *Planning and carrying out investigations;*
- *Analyzing and interpreting data;*
- *Using mathematics and computational thinking;*
- *Constructing explanations and designing solutions;*
- *Engaging in argument from evidence;* and
- *Obtaining, evaluating, and communicating information*."

Teachers are also advised to make positive statements to communicate their belief in students' scientific abilities and to use scaffolding (or breaking learning up into components) to support comprehension of challenging content. Overall, teachers may need more training in this area to connect the dots between the course subject and the application.

PUBLIC AND STUDENT PERCEPTIONS OF ENGINEERING

The research shows that a significant barrier to young people pursuing a career in engineering is "*deep-rooted misconceptions about the profession"* [8]. Traditionally there has been a stigma attached to engineering as being elite and complex. Although the profession is well-regarded by the public, there appears to be an overall lack of understanding of what an engineer is and what they do. In general, people perceive engineers as people who build things and do things; the profession is also associated with long work hours, work that involves little variety, and potentially dangerous work. Unfortunately, engineering is generally not perceived as making the world safer or finding solutions to improve people's lives.

In terms of student perceptions, research shows that while most students enjoy STEM lessons, they perceive it to be a difficult subject that is only for the most '*brainy*' students [8]. Many also perceive it as having little relevance to their real-world lives and interests. Such views are often reinforced by parents, peers, and even teachers. Further, there appears to be a lack of career education that gives students an overview of potential career paths for engineers. This concept was reinforced by key-informant interview respondents, who shared other common stereotypes such as, "*you have to be good at math*" or that "*most engineers are civil engineers*."

> *"There is a perception of engineers as building things and doing things; they are not perceived as making the world safe or finding solutions to improve people's lives."*
>
> Quote from key-informant interviews

The Royal Academy of Engineering & the Engineering and Technology Board in the UK provide several recommendations to improve student perceptions of engineering. Specifically, students respond positively when the curriculum demonstrates that…

- "*Engineers design products that they value, including mobile phones, clothes, sports equipment, computer games, etc.;*
- *Engineers work in a vast range of industries - aerospace, computer gaming, energy production, environmental protection, fashion, film and TV, healthcare, music, etc.;*
- *Engineering is a highly creative process where you use your imagination to solve problems;*
- *Engineering involves teamwork and interacting with people;*
- *Engineers use the latest cutting-edge technology;*
- *Engineers are shaping the future;*
- *Engineers have a positive impact on society and individuals;*
- *Many types of people choose engineering as a career;* and
- *Engineers have many opportunities to travel and work abroad*." [8]

To maximize the impact of these messages it is important that they also reach teachers, parents, and career advisors.

EDUCATOR PERCEPTIONS OF ENGINEERING

Although teachers strongly believe in the value of STEM education, some have self-identified as *not qualified in teaching engineering* [5]. A report from the Toronto School Board (2016) found that teachers reported not feeling entirely comfortable teaching EDP and that a lack of resources, such as funding, equipment, and supplies, are barriers to teaching EDP concepts. An additional study out of the US found that although most teachers do support the inclusion of engineering within K-12, there are multiple perceived barriers to teaching engineering, including:

- "*Lack of pre-service and in-service training;*
- *Lack of background knowledge;*
- *Lack of materials;*
- *Lack of time for planning and implementing lessons;* and
- *Lack of administrative support*." [9]

Further research has linked students' lack of interest in engineering to teachers being underqualified; particularly teachers who were in service before STEM became a priority for most countries [10]. Besides providing extra training for these teachers, the authors suggest increased access to university outreach programs and introducing curriculum and institutional changes by implementing formal assessment metrics in engineering learning (similar to what happens with mathematics and science). Meanwhile, Goodnough and colleagues (2014) report that teachers perceive *"time, opportunities to collaborate,* *provision of resources, technology access, and support and guidance from the administration, program specialists, and researchers*" as key features of what is needed for success [11].

A lack of confidence in teaching engineering processes was discussed in the key-informant interviews. A respondent indicated that "*teachers can become intimidated and hide behind the curriculum",* and it is difficult to network with some teachers to build confidence in engineering. For many organizations, there is a lack of understanding of what is going on in the classroom as it is tough to get access to student data due to privacy restrictions.

> *"Teachers can become intimidated and hide behind the curriculum. It is important to build confidence in teachers and demystify what engineering really is."*
>
> Quote from key-informant interviews

SOCIOECONOMIC STATUS AND MINORITY GROUPS

Research indicates that youth residing in low-income households are "*disproportionately affected by psychosocial barriers, which often inhibit meaningful engagement in STEM programming*" [2]. These barriers may include a lack of finances for quality STEM education and a lack of access to or awareness of STEM programs, mentors, and career paths. According to the American Society for Education, as little as 3.5% of surveyed engineering students came from the lowest socioeconomic bracket based on the US census definitions [12]. They also found that students from lower socioeconomic backgrounds were less likely to have experiences with STEM before college.

This concept was discussed in the key-informant interviews: one respondent shared that application fees for engineering programs may be cutting access for Black youth by up to 90%. Specifically, when application fees were removed at their university, uptake by students in that demographic tripled. The main barriers students from marginalized groups reported experiencing are: location, access, and finances. There are also fewer teachers and programs available in areas of low socioeconomic status and students need additional resources such as technology.

> *"We tend to see less teachers working in areas where we might experience some socioeconomic struggles layered on top of a high number of racially identified students."*
>
> Quote from key-informant interviews

To address the underrepresentation of youth from low-income communities, Duodu and colleagues (2017) recommend delivering STEM programming within a community context, while offering opportunities for consistent engagement and positive youth-staff relationships [2]. Overall, it is essential that marginalized youth have access to after-hours STEM teaching programs. Beyond the positive personal outcomes for each student, the authors found that the more youth such programs attract now, the more they will be able to attract in future, as students who complete the program act as advocates to their friends and colleagues.

2.2. Proven Approaches to the Successful Incorporation of Engineering in K-12

It follows from our previous discussion that the successful incorporation of engineering in the K-12 education system should address challenges that stem from the systemic and psychosocial barriers discussed previously. The literature points to several best practices to remove barriers and increase youth engagement in engineering. Three prominent approaches are discussed below:

4. Mentorship and Role Models
5. Engineering & STEM Programming within a Community Context
6. Pre-K Engagement

MENTORSHIP AND ROLE MODELS

Mentorship programs or engineer role models may play a significant role in the recruitment and retention of engineering students [13]. Such initiatives bring professional engineers directly into the K-12 classroom to connect with students and share more about the profession. In Canada, Engineers of Tomorrow hosts the *Engineer in Residence* program, which allows students to connect with an 'engineering role model' who ultimately improves students' understanding of what engineering is [14]. This non-profit organization works closely with teachers and engineers to "*develop a program of activities to support curriculum learning in engaging and novel ways*."

In the key-informant interviews, one respondent shared that "*repeated exposure to what engineering looks like can create a lasting impact"* and may also address barriers to the retention of students such as public and student perceptions of engineering. In their program, mentors are given strategies on how to talk to students about engineering in an inclusive way and are encouraged to share their own stories and connect with students on a personal level before discussing the technical aspects of the profession.

> *"We teach engineers how to talk to kids about engineering in an inclusive way with strategic messaging. They integrate their own personal story and connect with students as a human first."*
>
> Quote from key-informant interviews

Mentorship can also provide an opportunity to engage students from diverse backgrounds such as women or minority groups. According to the National Alliance for Partnerships in Equity (US), "*one of the most effective ways to encourage students to consider non-traditional careers is to introduce them to diverse role models, particularly role models with whom they can relate, by gender, ethnicity, socio-economic status, location, etc."* [15]. Similarly, Pritchett (2021) shared that students who think *"they look like me!"* may be more likely to engage in STEM subjects and change their image of what a '*scientist*' looks like [16]. Overall, it is clear that engineering mentors and role models have a positive effect on student engagement in the field.

ENGINEERING/STEM PROGRAMMING WITHIN A COMMUNITY CONTEXT

To further engage youth in STEM or engineering programming, Duodu and colleagues (2017) recommend delivering STEM programming within a community context while offering opportunities for consistent engagement and positive youth-staff relationships [2]. This concept is echoed in the literature with other studies showing that community-based learning (CBL) for STEM has "*the potential for positive student learning outcomes while also promoting beneficial outcomes in partner communities"* [17]. Availability of STEM learning in the community may be particularly important for learners from minority groups or low socio-economic status, who may not have access to STEM learning at home. This concept was discussed in the key-informant interviews – one respondent stressed the importance of developing partnerships at the local level, commonly with organizations such as the Boys and Girls Club.

> *"Community work is often in concert with another organization such as the Boys and Girls Club. It is very important to develop partnerships at the local level."*
>
> Quote from key-informant interviews

Community-based outreach units may also play a critical role in encouraging student involvement in STEM. Scott Compeau (2021) reports that a key strategy involves the promotion of K-12 STEM learning ecosystems: a combination of formal learning experiences provided by educators within schools and informal learning experiences that are supported by stakeholders such as parents, community-based youth organizations, post-secondary institutions, government and other K-12 STEM outreach units [18]. Examples of informal STEM learning experiences include after-school programs, summer camps, and library programs. Combined, these learning experiences act as STEM knowledge brokers: defined as "*a person or organization that facilitates the creation, sharing, and use of knowledge between at least two or more groups*".

PRE-K ENGAGEMENT

Although most STEM outreach initiatives focus on children in junior high and high school, Tippett and Milford (2017) make the case for STEM learning in early childhood education, including pre-kindergarten (Pre-K) [19]. Their study revealed that young Pre-K students actively engage in STEM activities and appeared "*eager to share their ideas about STEM*". Further, parents responded positively to STEM initiatives in their child's Pre-K classroom and were even interested in learning how to incorporate STEM concepts in their interactions with their children. The authors concluded that STEM education is an appropriate component of early childhood education and may promote a range of STEM-related skills including "*questioning, play, processing skills, and scientific and engineering practices*". Thus, to increase the likelihood of engaging students in STEM, it appears that promotion should start well before students reach high school age.

> *"Pre-K students actively engage in STEM activities and appeared eager to share their ideas about STEM."*
>
> Milford, 2017

Pre-K engagement also came up in the key-informant interviews – one respondent shared that in early years, there is generally an even split of young students interested in STEM. However, as students age, this then shifts to more males in STEM programming. Therefore, early STEM engagement may present a key opportunity for the retention of females in STEM and engineering fields.

2.3. How STEM Has Incorporated Engineering Concepts

The literature review and key-informant interviews revealed that engineering is typically used as a context to explore STEM rather than a subject of its own. Typically, there are no engineering slots on the school timetable; rather, it is partially embedded into the curriculum through the use of engineering tools such as science or math that are being taught and tested. As mentioned previously, end-of-unit projects are also a key tool to embed engineering into the curriculum. However, one key-informant interview respondent stated that "*it is a struggle to get engineering in the curriculum beyond the surface level".*

Studies suggest that engineering practices are a "*key pillar*" of a well-rounded STEM education [20]. Specifically, concepts such as problem scoping, identifying multiple solutions, and testing and improving solutions facilitate learning development which can lead to a more comprehensive understanding of STEM fields. In addition, Simarro and Couso (2021) suggest that engineering education can *"improve students' learning in science and mathematics (by providing, for example, a context in which to test scientific knowledge and apply it to practical problems), increase knowledge of engineering and the work of engineers, increase students' technological literacy, and stimulate young people's interest in pursuing engineering as a career"* [20].

Meanwhile, Householder and Hailey (2012), argue that "*engineering design can be integrated into STEM curricula to provide a mechanism through which students learn relevant STEM content"* [21]. Specifically, students should develop "*engineering habits*" which result in multiple learning outcomes for students such as solving structured problems with problem-based learning (PBL) approach. Key steps in an engineering design challenge include:

- *"Step 1: Identify need or problem*
- *Step 2: Research need or problem*
- *Step 3: Develop possible solutions*
- *Step 4: Develop the best possible solution*
- *Step 5: Construct a prototype*
- *Step 6: Test and evaluate the solution*
- *Step 7: Communicate the solution*
- *Step 8: Redesign*
- *Step 9: Finalize design".*

  *All steps are interconnected [21].

> *"It is a struggle to get engineering in the curriculum beyond the surface level."*
>
> Quote from key-informant interviews

INTERNATIONAL INITIATIVES

Incorporating engineering concepts into STEM teaching is not only a priority in Canada and the US, several other nations outside of North America have a desire to see their children and youth educated in these areas. Although countries seem to share a similar objective (to enhance their performance in STEM and increase student post-secondary enrollment in the field), the practices they adopt to achieve this differ. Some prefer to focus on classroom-based teaching, others adopt a hands-on approach in which students can participate in apprenticeship programs, and some use a mix of both. Insights from practices adopted in Australia, Scotland, and Ireland to address engineering teaching are discussed below.

In Australia, engineering teaching in the F-10 system (equivalent to the North American K-12 system) occurs in two ways:

1. Specific engineering subjects in the Design and Technologies strand of the curriculum; and
2. Across three learning areas: Science, Technologies, and Mathematics [22].

According to Engineers Australia, by undertaking engineering projects within other STEM learning areas students can develop an understanding of fundamental concepts of engineering:

- *"ASK: Understand the problem, identify constraints, and technologies available to solve the problem;*
- *IMAGINE: Identify possible solutions, estimate solution effectiveness;*
- *PLAN: Identity how will the solution be implemented, identify technologies and processes to be used;*
- *CREATE: Build the solution and test it;* and
- *IMPROVE: Evaluate test results identify areas for improvement, implement improvements"*.

Australia also fosters partnerships between schools and industry, universities, and the community to support such learning in the country's schools. These partnerships aim to lower the gap between students' classroom learning and their expectations about career and higher education opportunities in STEM-related areas [23]. Further, Australian research shows that partnerships between university professors and schoolteachers enhanced students' experiences on engineering projects. The main outcomes were increased authenticity of the projects and increased sophistication of students' feedback when assessed by external reviewers.

Meanwhile, in Europe, the country of Scotland utilizes apprenticeship programs to integrate engineering into their curriculum. The Government of Scotland views colleges and universities as bridges between formal education and the labour market, with the former providing skills to meet the latter's needs. To close the gap between the two, students are given an opportunity to participate in apprenticeships throughout their studies [24]. Colleges are responsible for delivering these programs in partnership with local industry employers. Typically, such apprenticeships allow students to focus on obtaining real-world experience and formal education while gaining internationally recognized qualifications.

In Ireland, STEM teaching happens across all education levels, from primary school to university. Notably, STEM components are identified and taught in typically non-related courses such as Geography and the Visual Arts [25]. In addition, Ireland provides incentives and training for teachers to promote STEM-related activities in schools. Engineering is typically taught in three learning strands: 1) processes and principles, 2) design application and 3) mechatronics. Students are then taught how to apply this knowledge to design and manufacture products. Furthermore, Ireland's Department of Education reports that by taking engineering courses, students enhance broader critical skills such as numeracy, creativity and literacy; they also learn how to manage information and learn how to work well with others.

CANADIAN INFLUENCERS & INITIATIVES FOR YOUTH

A jurisdictional scan to identify current engineering-related K-12 influencers and initiatives for Canadian youth was conducted. Key organizations and programs across Canada that support STEM or engineering-related K-12 initiatives are presented, along with eleven key types of initiatives: camps, teacher professional development and resources, classroom visits, mentorship, summer employment programs, tournaments or competitions, funding, networking, community events and gender-based initiatives.

3.0. Canadian Influencers & Initiatives for Youth

A jurisdictional scan of publicly-available data identified organizations and programs across Canada that support STEM or engineering-related K-12 initiatives for youth.

STEM innovation in the Canadian K-12 school system has increasingly become a priority in Canada. The federal government has funded several initiatives to incentivize STEM and engineering-specific learning among K-12 students and other marginalized populations, such as women. For example, the Natural Sciences and Engineering Research Council of Canada (NSERC) funds several key initiatives including:

- NSERC Young Innovators: provides grants for organizations to incentivize youth participation in engineering-related competitions;
- NSERC Chairs for Women in Science and Engineering Program: focuses on enhancing the participation and retention of women in engineering and science fields; and
- PromoScience: provides funds for organizations to disseminate STEM awareness among youth [26].

Of particular importance, PromoScience provides funding to key organizations such as Actua and Let's Talk Science. Actua is the largest STEM outreach and networking organization in Canada and is present in over forty Canadian universities and colleges [27]. In addition to supporting many outreach activities from its members, Actua has programs such as "*Go Where Kids Are*," which target communities that may not have access to traditional university-based outreach programs.

Let's Talk Science also organizes outreach activities through universities [28]. Like Actua, it provides resources for teachers to use in the classroom, such as videos or interactive activities. In addition, it includes training for teachers to improve their STEM teaching skills. In 2020, Let's Talk Science reported more than 190,000 people accessed their digital resources during school shutdowns due to the COVID-19 pandemic and over 4,000 schools used their resources. Both organizations seem to be playing an essential role in diffusing STEM knowledge to Canadian youth.

In terms of organizations or individuals with an engineering-specific focus, there is less consensus on top influencers in the K-12 space. Although there are currently several organizations doing work in this area, there is no one organization or influencer that stands out as leading the way in engagement and promotion of the field of engineering in K-12.

Through key-informant interviews and an online survey, representatives at Canadian organizations that support engineering initiatives for youth were asked to share who they felt were the key influencers in the field for K-12. Although Actua and Let's Talk Science were indicated more than once, overall responses revealed little consensus around who the key influencers are in leading engineering promotion in and out of the classroom among K-12 students in Canada.

3.1. Jurisdictional Scan of STEM and Engineering Organizations

The jurisdictional scan aimed to gain an understanding of how engineering is currently represented in the Canadian K-12 system and what Non-Government Organizations (NGOs) and education boards are doing to promote and incorporate engineering in STEM learning. The scan was conducted through a comprehensive search of national programs that promote STEM or engineering-related educational initiatives for youth.

The jurisdictional scan was also informed by data from the online survey, which at the time of writing had received a total of 20 completes. A summary of the jurisdictional scan is provided in Appendix A.

The full scan was provided in a separate document and is available upon request.

Data from the scan was used to create a K-12 Outreach Ecosystem Map, which can be accessed here: Engineers Canada K-12 Outreach Ecosystem Map

3.2. Engineering-Related Initiatives for Youth

Secondary research identified eleven key types of engineering-related initiatives available to youth in Canada:

1. Camps
2. Professional Development for Teachers
3. Resources for Teachers
4. Classroom Visits
5. Mentorship
6. Summer Employment Programs
7. Tournaments and Competitions
8. Funding
9. Networking
10. Community Events
11. Gender-based Initiatives

Each of the initiatives are summarized in the table on the following page.

Summary Table of Engineering-Related Initiatives for Youth

Initiative	Overview	Sample Programs
Camps	Typically offered in the summer months, camps expose students to a series of activities related to engineering and other STEM subjects, allowing them hands-on experience in a real-life environment. The content of the camps varies according to the grades, but common topics include coding and robotics.	Actua's "Nano Engineers" WISE Kid-Netic Energy "energy stem camps" UBC Geering Up Engineering Outreach "High School Summer Camps"
Professional Development for Teachers	Several organizations offer teachers the resources to enhance their skills in STEM subjects and techniques to integrate these topics into their classrooms. The goal of these initiatives is to improve learning outcomes by better preparing teachers to teach content. Programs are delivered through various methods, such as in-person events and online seminars.	Queens University - Connections Engineering "Connections Educational Technology Conference" SCIENCE AL!VE "Teacher Professional Development" Alberta Science Network "Plant Growth and Changes, Grade 4"
Resources for Teachers	Most STEM organizations offer various teaching resources for K-12 educators. Access to these resources is easy as they are available for free download on many organization websites. Sample of resources include games, pre-recorded workshops, interactive activities, and hands-on projects.	Ontario Science Centre "STEM Education Toolkit" Pinnguaq "Let's Get Bees-y" Alberta Women's Science Network "Operation Minerva Planning Guide for Educators"
Classroom Visits	These initiatives consist of professionals in a STEM field, such as Engineers or Scientists, visiting classrooms to present one of the topics included in the school's curriculum. Besides explaining their topics, the invited professionals discuss the relevance of their profession and provide hands-on experiences.	Let's Talk Science at the University of Toronto "Classroom & Community Visits" EUReKA "Workshops" Science Venture "Light and Sound (Grade 1)"

Mentorship	Mentorship projects are designed to pair prospective students of STEM fields with experienced professionals. The objective of these projects is to give individualized orientation to students and open a direct channel through which students can ask questions, get advice, and share concerns. In addition, it is considered one of the first networking steps in the student's professional development.	Students on Ice "SOI Mentorship Program" WiseNL "Mentorship Program" Canadian Black Scientists Network "Mentorship Program"
Summer Employment Programs	Some organizations provide secondary students with the opportunity to work in paid STEM-related positions during the summer. The objectives of these programs are to provide hands-on experience, encourage students to consider careers in STEM, and show students careers in these fields can be exciting and rewarding.	WiseNL "Summer Employment" Women in Scholarship, Engineering, Science, and Technology "Summer Research Program"
Tournaments and Competitions	Some outreach organizations organize tournaments and challenges among students in STEM subjects such as robotics, coding, engineering, and science. The goal of these tournaments is to provide students with the chance to test their knowledge and reward their interest in STEM.	Quebec Confederation for Engineering Student Outreach "Quebec Engineering Competition" DiscoverE "Future City Competition"
Funding	Funding organizations function in different ways. They can be either governmental or non-governmental and their objective is to subside initiatives in STEM. Organizations can provide funding directly to students, such as scholarships to newly admitted university students, or finance other initiatives, such as workshops and events.	Natural Sciences and Engineering Research Council of Canada (NSERC) "Young Innovators" MindFuel "Scholarships for Young Innovators"
Networking	Organizations that promote networking do so in two different ways: The first focuses on enhancing students' connections among themselves, among them and professionals, and among post-secondary students. The second are organizations responsible for promoting connections between organizations, allowing them to assist each other and share useful information.	Actua "Network" Poly-ϕ "Sponsorship Program" Alberta Women's Science Network

Community Events	Community events are held by various organizations and are prepared to increase awareness of STEM topics in the regions they are held. Such events target children and teens and can happen in multiple ways such as workshops, open experiments, or professional talks.	Westcoast Women in Engineering, Science, and Technology ”Burnaby Festival of Learning” Brilliant Labs “Prototyping, Coding & Inventing” Let's Talk Science at the University of Victoria “Rural Visits”
Gender-based Initiatives	Gender-based initiatives aim to provide STEM training specifically to girls enrolled in kindergarten to grade 12. These programs are created based on the perception that very few girls/women are enrolled in STEM programs or working in STEM occupations, leading to a majoritarian presence of men.	UBC STEM Outreach Collective “GIRLsmarts4tech” hEr VOLUTION “STEMing UP” Engendering Success in STEM “Project CLIMB”

ANALYSIS OF ENROLLMENT DATA

Provincial and territorial governments are responsible for establishing school curricula. As a result, some provinces do not mention engineering at all and others include engineering as a learning outcome or have dedicated courses on the subject. Currently British Columbia, Manitoba, Ontario, Quebec, Yukon and the Northwest Territories all include engineering in their curriculum.

Although overall enrollment information was available, access to existing K-12 student-level enrollment data is limited. Student-level data is needed to identify engineering program eligibility, audiences that are underrepresented and jurisdictions where K-12 approaches to engineering are resulting in a high number of students with the potential to pursue engineering at a post-secondary level.

4.0. Analysis of Enrollment Data

Enrollment data can be examined to provide objective year-over-year data on the number of students graduating from grade 12 with the qualifications to apply to most post-secondary engineering programs in Canada. Data was gathered from across Canada to examine the relationship between the number and demographics of students graduating from high school with the necessary prerequisites to pursue an undergraduate degree in engineering

Enrollment data was obtained from 10 provinces and 2 territories. [1] However, due to privacy restrictions, the data was aggregated in such a way that it was not possible to determine the number of students graduating with the potential to pursue an undergraduate degree in engineering. Post-secondary admission requirements for engineering programs across Canada consist of a combination of prerequisite classes, often with minimum grade requirements, as well as a minimum average grade requirement across all coursework. Appendix F provides a high-level summary of application requirements across post-secondary engineering programs in Canada.

Although numbers for individual course enrollments were provided, it was not possible to determine the combination of classes a student may graduate with or an average grade across classes.

4.1. Provincial Curriculum

Canada does not possess a national curriculum. Instead, the provincial and territorial governments are responsible for establishing the curricula for their schools. Common courses across all provinces include language, mathematics, science, social studies, art, and citizenship education. Because of the lack of centralization on what is taught in Canadian schools, the way provinces integrate engineering into their curriculum largely differs. Some provinces do not mention engineering at all, while others have multiple dedicated courses to the subject. Provinces that make no mention of engineering are Alberta, Saskatchewan, New Brunswick, Nova Scotia, Prince Edward Island, Newfoundland and Labrador, and Nunavut. Meanwhile, British Columbia, Manitoba, Ontario, Quebec, Yukon, and the Northwest Territories all include engineering in their curriculum.

British Columbia, Northwest Territories, and Yukon

British Columbia, the Yukon, and the Northwest Territories all share the same curriculum. British Columbia developed it and it was last updated in 2014. The province implemented changes to allow students to remain current in today's world, where new technologies emerge frequently, and information is instantly transmitted. The province's curriculum aims to develop three core competencies: communication, thinking, and personal and social capability. In addition, a key objective is to ensure students develop solid numeracy and literacy foundations.

[1] At the time of the publishing enrollment data had not been received for Nunavut.

All areas of learning present in BC's curriculum are based on a "*know-do-understand*" model. "*Know*" refers to the essential knowledge students will get in touch with at each grade. "*Understand*" is the generalization of key concepts and principles. "*Do*" refers to the skills and competencies students acquire over time. BC's curriculum also offers a mix of "*concept-based*" and "*competency-driven*" learning.

Engineering is taught in BC's curriculum in grades 11 and 12 as specific courses (named Engineering 11 and Engineering 12) under the Applied Design, Skills, and Technologies field. In these courses, students are expected to learn about the history of manufacturing and production, product development and manufacturing processes, manufacturing to meet the needs of the end-user, sustainable production, upcycling, mathematics, and measurement techniques in engineering projects. In addition, students are expected to learn and apply safety procedures, develop skills involving manual dexterity and develop specific plans to learn or refine skills over time.

Manitoba

Manitoba's curriculum is based on four foundation skill areas: literacy and communication, problem-solving, human relations, and technology. These skill areas are present in the instruction of every subject area and encompass the "*what*" to learn and "*how*" to learn. The province also includes key aspects of the curriculum, Aboriginal perspectives, sustainability, and diversity.

In Manitoba, engineering is offered in the Technology Education field from grades 9 to 12. Technology Education aims to teach students how to use technology to create practical solutions to problems and develop technical skills. According to Manitoba's Department of Education, "*The ability to adapt to a changing technological society and to accept social responsibility is paramount to all Manitobans in the pursuit of new careers and lifestyles. Technology Education allows learners to evaluate their strengths and interests in career choices. It also reflects rapid changes in the workplace and allows students to make informed decisions about their future*". In Manitoba, engineering courses are part of the province's technical-vocational education program, in which students get the required skill training to join the job market. The province also offers Mining Engineering Technology and Sound Engineering Technology programs, from introductory to advanced levels.

In the Mining Engineering program, students are expected to develop knowledge regarding safety, geology and geophysics, computer applications in mining, and ground control, among other things. Additionally, the program allows students to get apprenticeship opportunities and may give them advanced standing in some post-secondary programs. Meanwhile, in the Sound Engineering program, students are exposed to various topics such as music theory and sound engineering for studio productions and live performances. Students are expected to develop other general skills, including health and safety practices and employability skills.

Ontario

The Ontario curriculum aims to offer a broad range of learning options to students, allowing them to customize their learning experience according to their skill and preferences. The province divides its curriculum into nineteen learning areas, including English, French as a second language, Mathematics, Science, Technology, and The Social Sciences and Humanities. Students are expected to develop transferable skills such as critical thinking and problem solving, self-directed learning, collaboration, communication digital literacy, and global citizenship and sustainability.

Engineering is taught in the Technological Education field which was developed in 2009. This area aims to enhance students' technological literacy, enabling them to understand, work, and benefit from different technologies. Courses are divided into university/college preparation courses, workplace preparation courses, and open courses. Some of the fundamental technological concepts students will get in touch with include fabrication, material, power and energy, mechanisms, and systems. Engineering-specific subjects are part of grade 11 and 12 programs, including computer engineering technology, construction engineering technology, and manufacturing engineering technology.

The computer systems engineering program teaches students to assemble computers and small networks. In addition, students also learn about electronics, robotics, and programming. Students in this program will also get advice about college and university programs that lead to a career in computer technology. The construction engineering program gives students the required knowledge and skills about residential and light commercial construction. Students get the chance to learn how to use a variety of materials, processes, tools and equipment. Lastly, students in the manufacturing engineering program learn about design, process planning, control systems, quality assurance and business operations. They use various tools and equipment and enhance their skills in computer-aided design. Like the other programs, students learn about career opportunities in the manufacturing industry.

In addition to specific courses in the Technology learning area, in 2022, the Ontario curriculum included scientific processes and engineering design process (EDP) as key learning topics in its Science learning area for both primary (K1-K8) and secondary (K9-K12) students. This largely differs from the 2007 science curriculum in that it did not mention EDP or any engineering-related topics specifically. The 2022 Science curriculum aims to provide students with various opportunities to develop STEM skills and encourages students to make connections between science and other subject areas. EDP is used to help students to develop their sense of wonder, their curiosity and to help them to investigate problems around them through practical steps. The new curriculum explains that EDP provides students and teachers with a framework to plan and build solutions to problems of the world around them. It also adds that there's no single EDP; instead, students will get in touch with various engineering practices to design projects. Some EDP skills students are expected to learn include researching and understanding problems, generating potential solutions, developing, testing, revising prototypes, and communicating the solution.

Alberta

Alberta's curriculum foundations are literacy and numeracy. The first ensures students can read and understand texts in English; the second aims to make sure students know how to use standard mathematical algorithms. Combined, these skills enable students to solve problems, think critically and become engaged citizens.

Alberta's curriculum has six subject-specific fields, they are language arts and literature, mathematics, science, social studies, physical education and wellness, and fine arts. None of these areas include engineering as an independent course; however, the province's curriculum does state that it possesses the required content within the Science field to prepare students to pursue engineering careers. In the Science field, students are required to learn various topics such as scientific methods, the basics for the understanding of the natural world, classification systems, human impact on the environment and climate and others. Related to engineering, the curriculum mentions that *"[students will learn] that scientific knowledge and skills are applied in areas such as engineering and design, technology, medicine, manufacturing, agriculture, robotics, social sciences, and space industry in ways that can continue to make life better"*

Quebec

Quebec's curriculum focuses on the development of competencies. It entails a different approach to knowledge development and focuses on teaching students to think and develop intellectual tools that will allow them to adjust and acquire new knowledge. Quebec's education program is based on three aspects: cross-curricular competencies, broad areas of learning, and subject areas. The cross-curricular competencies include intellectual, methodological, personal and social and communication development. The general areas of learning (i.e. the educational objectives) are health and well-being, personal and career planning, environmental awareness and consumer rights and responsibilities, media literacy, and citizenship and community life. Finally, the subject areas include Languages, Mathematics, Science and Technology, Social Sciences, Personal Development, and Arts Education.

Students learn engineering under the Science and Technology subject area offered during cycles one and two of secondary studies. Students focusing on the Science and Technology subject area are expected to develop the following competencies: "*Seek answers or solutions to scientific or technological problems; Make the most of his/her knowledge of science and technology; Communicate in the languages used in science and technology*". Related to the first competency, the program expects students to learn how to define problems, choose scenarios for investigation, conduct experiments, analyze results, build prototypes and test these prototypes. Related to the second, students are expected to learn basic concepts needed to understand scientific phenomena and analyze technical objects. Finally, the third competency expects that students will be able to communicate their findings using the appropriate scientific language and tools.

In Quebec's curriculum, engineering is not taught as a specific subject but as a general concept underlining other science and technology courses. Associated with engineering, students learn concepts such as the design and analysis of technological systems. Students learn the properties and how to use different materials like plastics, ceramics, and composites. The program also teaches concepts related to specific fields of engineering. For example, students learn the fundamentals of mechanics such as the transmission and transformation of motion, the linking of parts, and the most common mechanical functions. Students also learn the fundamentals of electricity, including the different electrical components and their operations including power supply, conduction, insulation, protection, control and transformation.

New Brunswick

New Brunswick curriculum is divided into ten learning areas from grades 1 to 5, eleven learning areas from grade 6 to grade 8, and twelve learning areas from grade 9 to 12. The high school (K-9 to K-12) learning areas include Experiential Learning, English Language Arts, French Second Language, Guidance, Health and Physical Education, Mathematics, Science, Social Studies, Skilled Trades, Applied Technology, Business, and Work-Ready Electives, Information Computer Technology, The Arts and Wabanaki Languages. Engineering is not included either as a learning area or as a course within other areas.

Engineering is only mentioned in the province's curriculum as a possible career a student may choose in the future due to the skills they learned. More specifically, engineering is briefly mentioned under the Technology field as one career students who develop design skills may pursue.

Prince Edward Island

Prince Edward Island curriculum provides appropriate development for children so that they may take a meaningful place in society. Among its goals, Prince Edward Island aims to develop students' ability to think critically, literacy, numeracy, respect for the community, and creative skills. The curriculum has multiple dedicated science courses including physics, chemistry, biology, and environmental science. Although there is a course called *Applied Science*, there is no explicit mention of engineering in the curriculum.

Nova Scotia

Nova Scotia's curriculum focuses on developing students' skills beyond foundational levels. Students of the province are expected to develop six "*essential graduation competencies*": citizenship, communication, personal-career development, creativity and innovation, critical thinking, and technological fluency. Under citizenship, students learn to contribute to the quality and sustainability of communities. In communication, students learn how to express themselves and interpret different kinds of media. Creativity and innovation teach students to engage in innovative processes and to demonstrate openness to new experiences. Critical thinking development was designed to teach students how to analyze and evaluate evidence using various types of reasoning and systems. Lastly, technological fluency expects students to use technology to collaborate, create, innovate, learn and solve problems.

The high school curriculum is divided into sixteen fields, ranging from arts to technology education. Although engineering is not particularly mentioned in any of the courses offered under these fields, the province offers courses that are related to some engineering professions such as construction technology, energy, power, transportation technology, and electro technologies.

Newfoundland and Labrador

The Newfoundland & Labrador curriculum aims to prepare students to continue learning even after they finish their studies. More than individual subjects, the curriculum proposes that students make meaningful connections between the different topics they are presented with. The province proposes seven essential graduation learnings: aesthetic expression, citizenship, communication, personal development, problem-solving, spiritual and moral development, and technological competence.

The NL curriculum has eighteen learning areas, which include arts, French, English, science, and others. The province does not have engineering as a course or as a learning area, but it mentions some courses that may be relevant to students who think about pursuing an engineering program. An example is the Robotics program in the technology learning field.

CONCLUSIONS & RECOMMENDATIONS

5.0. Conclusions and Recommendations

This report brings together several research approaches to provide an overview of how engineering is being incorporated in K-12 in Canada today. Although there are gaps in available data, this research integrated with best practices and insights from other jurisdictions can provide some evidence-based direction for increasing engineering engagement in K-12.

The following conclusions and recommendations provide a summary of our findings and a recommended path forward, to increase the number and diversity of qualified engineers prepared to participate in the Canadian workforce.

ENGINEERING IN K-12 IN CANADA

How has STEM education incorporated engineering concepts?

The presence of engineering as part of STEM in the classroom varies widely. Overall, engineering appears to be under-represented or unidentified in the K-12 classroom. This is due, in part to a lack of explicit inclusion of engineering as a learning outcome/goal early in the Canadian curriculum; and the language used to describe engineering exercises and concepts in the classroom.

Engineering-specific targets are missing from many K-12 curriculums nationally

The lack of centralized curriculum in Canada means there is no one push toward specific goals to achieve in K-12.

Nationally, curriculums vary in how they treat Engineering in K-12. Some provinces, like British Columbia, have engineering as a course offering while others do not explicitly identify engineering as a learning outcome or goal.

Where incorporated, Engineering is brought in late to the curriculum. In markets where Engineering is specifically incorporated into the curriculum (e.g., British Columbia, Manitoba) it is in later years (junior high or later). The findings from the literature review indicate that earlier engagement in the classroom can lead to increased interest in the subject.

Lack of understanding of what constitutes engineering among educators

As the literature review indicates, educators may have difficulty teaching engineering due to a lack of understanding of the language and models used to incorporate engineering concepts into the classroom. This was confirmed and reinforced in the key-informant interview findings and is unsurprising given that many curriculums in Canada do not recognize engineering as a unique subject from the rest of STEM.

The absorption of the word *engineering* in “STEM” within the K-12 space is a key takeaway. K-12 students and educators may not be aware that engineering-based activities are actually engineering. Our research suggests that educators and organizers are facilitating a breadth of engineering-related activities in the K-12 space, but it is not labeled as such and is obscured by framing these activities broadly as "STEM".

Without the clear inclusion of engineering in the K-12 curriculum, it will likely be a challenge to build educator confidence in teaching engineering concepts. As one key informant highlighted: "*Teachers can become intimidated and hide behind the curriculum*". It follows that by building it into the curriculum, both educators and learners will have a much better chance of being exposed to the concepts during K-12.

Ultimately, engineering is lost in 'STEM' in the K-12 space – many educators do not have a clear understanding of what engineering is. Although the jurisdictional scan indicates that engineering is being taught in the classroom, students with a growing passion for engineering may not consider engineering as a path simply because it is not named or well-defined in the K-12 space.

The findings point to the opportunity for consistent delivery of engineering curriculum nationally;

The integration of engineering as an explicit curriculum item may help encourage educators to use the word *engineering* and support students' understanding of what engineering is.

Examples of Engineering Initiatives and Practices Happening in K-12 Across Canada

Although it is challenging to get a view of exactly how engineering is represented within STEM learning in the classroom, many organizations work to promote engineering in K-12 in Canada. Organizations across Canada are providing programs and resources to educators and youth in and outside of the classroom. Secondary research identified eleven key types of engineering-related initiatives available to youth in Canada:

1. Camps
2. Professional Development for Teachers
3. Resources for Teachers
4. Classroom Visits
5. Mentorship
6. Summer Employment Programs
7. Tournaments and Competitions
8. Funding
9. Networking
10. Community Events
11. Gender-based Initiatives

Although there are some partnerships and collaborations, many of these organizations operate independently of one another without a shared goal or larger focus to drive an increase in the number of qualified engineers nationally.

MEASURING PROGRESS AND EVALUATING WHAT WORKS

In attempting to identify best practices for engineering programming and initiatives for K-12 it can be noted both in the literature and through one-on-one interviews that very little objective data is available. Similar challenges were present in attempting to establish a baseline for how many students nearing post-secondary might qualify to pursue engineering as a career path.

Access to existing K-12 student-based data about enrollment is limited in terms of what can be accessed. While high-level demographics exist, student-level data to help show the proportion of students with engineering readiness, their performance in the required prerequisite classes, and demographic details, were not accessible. The ability to identify student audiences that are underrepresented, jurisdictions where K-12 approaches to engineering are performing well and the effectiveness of key drivers are limited without access to student-level data. Limited access to student-level data also prevents the long-term ability to benchmark provincial performance and track that performance over time against goals.

There is also a lack of data available to evaluate the success of individual programs and initiatives being implemented by organizations promoting engineering in K-12. Although interview respondents often cited a lack of capacity and funding as challenges in conducting thorough program evaluations, this makes it difficult to continuously build on and improve programs and identify which efforts have the most success.

Moving forward, the best way to establish and identify best practices to support K-12 goals and engagement in engineering and track the potential to meet future labour market needs is to close the gap in data collection and availability

The following three research initiatives are recommended to establish benchmarks and to enable the evaluation of efforts to increase engagement in K-12:

- **Establish a shared provincial enrollment database for K-12 students**: This means establishing a data collection framework, identifying appropriate partners who own the information collection, and generating annual reports from the information to help inform decision-making.
- **Shared performance indicators for key initiatives & organizations:** While we identified eleven key types of initiatives, without information on how these initiatives are translating to engineering engagement, it prevents opportunities to define best practices and approaches for engineering specifically.
- **Undergraduate research of engineering students**: Given that establishing longer-term tracking frameworks will take time, an immediate recommendation is to conduct research among students enrolled in post-secondary engineering programs. The goal here is to help uncover the common underlying drivers behind their journey to engineering; in particular, common themes among women and underrepresented groups.
    - Important questions to explore include:
        - Did they engage with any extracurricular engineering and/or STEM programs? If so, which and when.?
        - Do they remember engineering concepts being taught in the class?
        - Do they remember engineering concepts being taught using the word engineering?
        - How did they end up pursuing engineering?
        - What initiative(s), if any, did they participate in?

RECOMMENDATIONS

Although the best practice research provided a number of valuable recommendations, we recommend that strategic priority be given to a few key areas for the most significant impact in moving forward engineering promotion in K-12 across Canada.

4. **A FOCUS ON LANGUAGE:** Promote the increased use of the word engineering in the classroom and increase educator confidence by establishing and promoting simple-to-understand shared definition and messaging.
    a. Establish a simple and shared definition of engineering that is appropriate for different grade levels.
    b. Communication campaign including definitions and messaging to support educators in identifying engineering concepts in STEM teaching and learning how to talk about engineering in the classroom.

5. **PROMOTE EXPLICIT INCLUSION OF ENGINEERING IN CURRICULUM ACROSS CANADA:** Advocate for engineering to be explicitly identified in K-12 learning objectives or outcomes in all provincial curricula, following the examples of British Columbia, Manitoba, Ontario, Quebec, Yukon, and the Northwest Territories. This essential move will help further encourage educators to talk about engineering more directly, using the right language in the classroom.

6. **ESTABLISH A MECHANISM TO GATHER AND UTILIZE SHARED DATA:** Utilizing shared data to encourage a focus on the right initiatives, promote collective advancement, and track progress.
    a. Advocate for access to a shared provincial enrollment database for K-12 students at the student level to track progress – only data necessary to determine if a student meets current requirements for entry into post-secondary engineering programs would be needed. This data would allow objective measurement in promoting the pursuit of engineering as a career path.
    b. Identify shared performance indicators for key initiatives & organizations to support program measurement and encourage data sharing.
    c. Establishing shared KPIs and collection of long-term data takes time, to inform existing programs and provide guidance on areas of focus it is recommended that a survey be conducted with post-secondary students currently pursuing engineering to identify the most effective initiatives and programs. This survey could also be utilized to validate the impact of having engineering explicitly stated in the provincial curriculum.

6. **INCREASE COMMUNICATION AND COLLABORATION:** Increased communication and collaboration are necessary to achieve the above goals. There are many wonderful initiatives and programs in Canada promoting engineering in the K-12 space; however, the lack of a leading voice or influence around the promotion of engineering in the K-12 space in Canada has resulted in smaller local impacts with most organizations working independently despite sharing similar goals and mandates. An increase in collaboration and communication opportunities would increase impact by allowing organizations to share lessons learned and maximize resources by working together.

7. **EXPLORE THE ADOPTION OF A COLLECTIVE IMPACT MODEL TO FACILITATE CHANGE:** Explore the benefit of utilizing a collective impact model as a proven approach to address the above goals to promote structured collaboration and systems-level change. See Appendix G for a more detailed explanation of collective impact and how the challenges identified in this report align with the functions of the collective impact model framework.

This report has provided a first look at how the 'E' (Engineering) is represented in STEM education and the landscape of K-12 engineering initiatives in Canada. The recommendations presented represent strategic direction to focus efforts on the promotion of engineering in the K-12 space to increase the number of Canadians choosing to pursue a career path in engineering.

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Appendix A: Jurisdictional Scan Summary

A jurisdictional scan was conducted to identify organizations that are delivering or promoting engineering initiatives for youth in Canada. It is important to mention that only organizations with some sort of engineering content – either specifically or generally combined with other STEM topics – were included. Institutions that delivered STEM projects unrelated to engineering were not included in the scan. The scan identified 82 organizations in total, with at least two organizations from each province. There were sixteen organizations identified in Ontario, twelve in British Columbia (12), seven in Quebec (7), and five each in Newfoundland and Labrador, and Nova Scotia (5). Fourteen (14) National organizations were identified.

The scan organized the organizations into three classifications. Type of program is the first classification and indicates whether they were engineering-specific or STEM-related (including engineering). The second is the type of initiative the organization worked on: awareness initiatives, delivery of programs, or both. Awareness organizations were entities responsible for promoting engineering or STEM to students through classroom visits, presentations, and events. Delivery organizations were organizations that delivered programs to enhance students' skills and knowledge about engineering or STEM subjects, such as summer camps, coding workshops, and lab activities.

The third classification relates to the type of organization: university-based or Non-Governmental Organization (NGO). University departments often host initiatives that are aimed at attracting new students to STEM fields. Although some independent organizations promote similar programs, they are essential to fill the gaps in university-based outreach programs such as engagement with rural communities or minority groups. NGOs often rely on funding provided by the provincial and federal governments and on the donations of individuals or private companies.

Looking at the type of program, most included engineering under the STEM umbrella instead of being exclusively focused on engineering. Fifty-seven (57) organizations delivered and promoted engineering programs alongside other STEM subjects such as coding or science camps. Twenty-five (25) organizations were engineering-specific. Ontario was the province with the most engineering-specific projects (8) while British Columbia had the highest number of STEM organizations (8). No engineering-specific organizations were identified in New Brunswick, Nova Scotia, Nunavut, Northwest Territories, Saskatchewan, or the Yukon.

When it comes to the type of initiative, out of the 82 organizations identified for this project, 17 promoted awareness, 50 delivered programs, and 15 did both. Ontario had the highest incidence of delivery organizations (12), while the highest number of awareness organizations were found nationally (5).

The scan identified 42 NGOs and 40 university-based organizations. Provincially, Ontario (13) and British Columbia (9) had the most university-based organizations, while provinces generally had an equal share of NGOs. The scan did not find any university-based projects for Nunavut and the Northwest Territories. A summary of findings from the scan is provided in the table below.

Province	Type of Program		Type of Organization		Type of Initiative			
	Engineering-Specific	STEM	NGO	University	Delivery	Awareness	Both	**Total**
Alberta	2	4	3	3	3	2	1	6
British Columbia	4	8	3	9	8	1	3	12
Manitoba	1	2	1	2	2	1	-	3
New Brunswick	-	3	2	1	3	-	-	3
Newfoundland and Labrador	1	4	3	2	3	-	2	5
Nova Scotia	-	5	2	3	4	1	-	5
Nunavut	-	2	2	-	1	-	1	2
Northwest Territories	-	2	2	-	1	1	-	2
Ontario	8	8	3	13	12	2	2	16
Prince Edward Island	2	1	2	1	2	-	1	3
Quebec	2	5	3	4	5	2	-	7
Saskatchewan	-	2	1	1	1	1	-	2
Yukon	-	2	1	1	1	1	-	2
National	5	9	14	-	4	5	5	14
Total	**25**	**57**	**42**	**40**	**50**	**17**	**15**	**82**

Appendix B: Survey Questionnaire

Survey assumptions:
- Type of survey: Online
- Sample: Target Engineering organizations from environmental scan; open link
- Length of survey: 5-7 minutes

Intro: MQO Research has been contracted by Engineers Canada to prepare a research report on how engineering currently fits into the K-12 space in Canada. A primary objective of this research is to prepare an ecosystem map of organizations that support science and engineering within the K-12 space in Canada. Please complete this survey to share more about your organization.

Q1. What is the name of your organization?

[Open-end] ______________________

Q2. What is your organization's primary mandate?

[Open-end] ______________________

Q3. In relation to engineering programming, does your organization…

01. Raise awareness and change perceptions of engineering
02. Deliver engineering programs
03. Provide both awareness and program delivery
04. Other (please specify): ____________________

[If Q3= 01 or 03] Q3b. What percentage of your initiatives are dedicated to engineering career awareness?

01. Less than 10%
02. 11-20%
03. 21-30%
04. 31-40%
05. 41-50%
06. More than 50%
98. Don't know
99. Prefer not to answer

Q4. Is your organization engineering specific or STEM?

01. Engineering specific
02. STEM
03. Other (please specify): ____________________

Q5. **[If Q3=02 or 03]** What types of programming does your organization deliver?
Please select all that apply.

01. Camps
02. Classroom visits
03. Mentorship
04. Teacher resources
05. Professional development for teachers
06. Summer employment programs
07. Tournaments and competitions
08. Networking
09. Funding
10. Gender-based initiatives
11. Community events
12. Other (please specify): ___________________

Q6. **[If Q3=02 or 03]** Approximately what percentage of your programs are designed for:

01. Youth aged 5-12 _________
02. Youth aged 13-17 _________
03. Youth aged 18-25 _________

Q6b. [All] Approximately how many youth does your organization reach per year?

[Open-end] _____________________

98. Don't know
99. Prefer not to answer

Q7. In your opinion, who are the top 5 influencers in engineering in the K-12 space in Canada?

[Open-end] _____________________

Q8. Does your organization have any strategic partnerships with other organizations in the sector?

Note that strategic partnership between organizations is defined as:
1. Working on a specific project or program together OR
2. Collaborating by sharing best practices or resources

01. Yes
02. No

99. Prefer not to answer

Q9a. **[If Q8=01]** Please list the organizations that you partner with on specific projects or programs.

[Open-end] ______________________

99. Prefer not to answer

Q9b. **[If Q8=01]** Please list the organizations that you partner with by sharing best practices or resources.

[Open-end] ______________________

99. Prefer not to answer

Q10. Engineering is the application of science and math to solve problems. While scientists and inventors come up with innovations, it is engineers who apply these discoveries to the real world. Does your organization use engineering-related activities to engage youth in STEM? If so, how?

[Open-end] ______________________

99. Prefer not to answer

Q11. Engineers Canada is interested in working with organization who are engaging youth (K-12) in STEM to help increase engineering career awareness. Would you be interested in learning more about how you could partner with Engineers Canada to move forward your youth outreach programs?

01. Yes
02. No

99. Prefer not to answer

Q11b. **[If Q11=Yes]** Please provide your email below and a representative from Engineers Canada will contact you.

[Open-end] ______________________

99. Prefer not to answer

Demographics

A few final questions that will be used for demographic purposes only….

D1. In which province or territory does your organization operate?

03. Alberta
04. British Columbia
05. Manitoba
06. New Brunswick
07. Nova Scotia
08. Newfoundland and Labrador
09. Prince Edward Island
10. Quebec

11. Saskatchewan
12. Northwest Territories
13. Nunavut
14. Yukon
99. Prefer not to answer

D1b. Is your organization a registered charity or NGO?

01. Yes
02. No
98. Don't know
99. Prefer not to answer

D2. How many full-time employees are employed by your organization?

[Open-end] ____________________

D2b. On average, how many parttime staff do you employ annually?

07. Less than 5
08. 5-10
09. 11-25
10. 26-50
11. More than 50
98. Don't know
99. Prefer not to answer

D3. Does your organization receive funding?

01. Yes
02. No
98. Don't know
99. Prefer not to answer

D4. **[If D3=01]** Who/what organizations do you receive funding from? *Please select all that apply.*

01. Foundations
02. Government grants
03. Corporate sponsors
04. Individual donors
05. Other (please specify): ____________
98. Don't know
99. Prefer not to answer

D4b. **[If D3=01]** Approximately how much funding does your organization receive per year?

[Open-end] ____________________

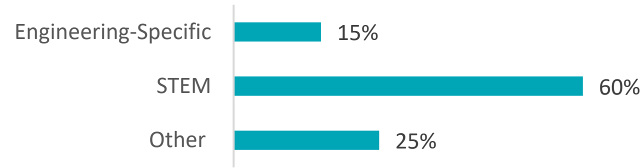
98. Don’t know
99. Prefer not to answer

This completes the survey. Thank you for your participation.

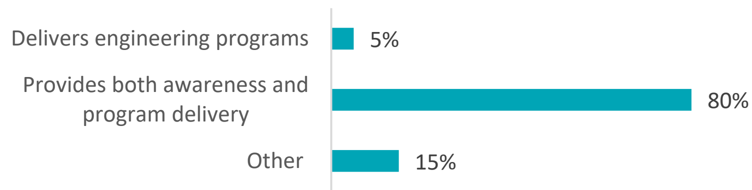
Appendix C: Survey Highlights

SURVEY HIGHLIGHTS (n=20)

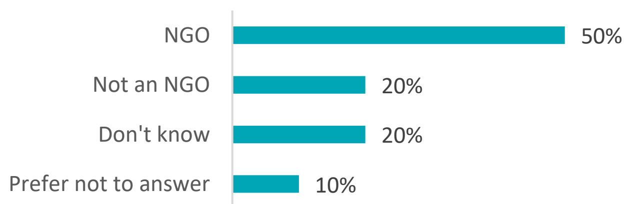
Type of Mandate



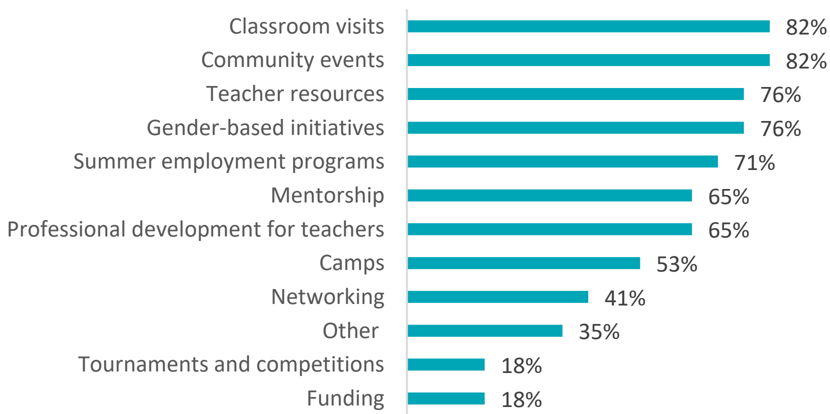
Type of Program



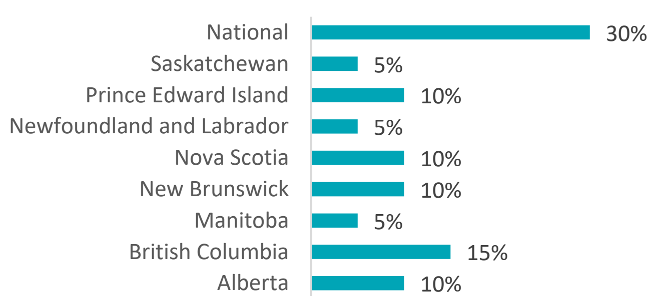
Type of Organization



Types of Initiatives* (n=17)



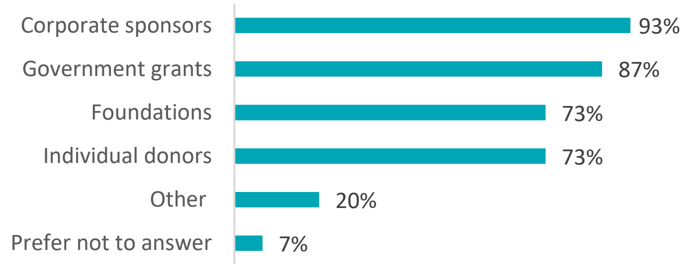
Province



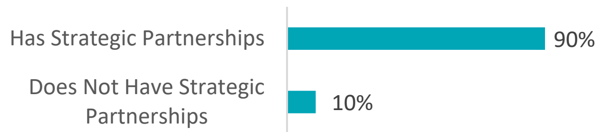
**Percentages may exceed 100% due to multiple responses.*

SURVEY HIGHLIGHTS (n=20)

Funding Sources* (n=15)



Strategic Partnerships



Other

	n	Amount
Average amount of funding received	7	$367,857
Average number of youth reached per year	14	13,300
Average number of full-time employees	14	9

**Percentages may exceed 100% due to multiple responses.*

Appendix D: Key-Informant Interview Guide

Interview assumptions:

- Type of interview: Phone or In-person
- Length of interview: 30-45 minutes
- Interview sample: Organizations from Jurisdictional Scan

Can you tell me a little bit about [org] and what you do?

What is your primary mandate?

What about specific to engineering?

What about specific to engineering in K-12?

In relation to engineering and kids coming up through K-12 is your role more..

1. *Provide supports for teachers to use*
2. *To raise awareness and change perceptions of engineering*
3. *More hands on actually going into the class and interacting with students*

How do you track success for your programs?

Based on your experience, how do you think STEM education in the classroom has incorporated engineering concepts or used engineering as a context to explore STEM?

How would you describe how engineering is presented to kids in K-12 in Canada today?

What do you think are the biggest challenges that need to be overcome in the K-12 space to encouraging more kids to pursue engineering?

If there were one thing you could change today about how engineering is taught in K-12 what would it be?

In your mind, who are the top influencers within the NGO sector that are supporting and/or contributing to engineering-related K-12 instructional materials and curriculum.

If STEM – is there any organization that is specifically focused on engineering that you think it making a big impact?

One of the things we've noticed is that there are a lot of people, or organizations in this space doing great work and we want to try and provide a bit of a map of what's going on in engineering in Canada to encourage opportunities for collaboration.

What organizations or partners is your organization connected to, either through collaboration, funding arrangements, shared goals?

What do you think are the best practices for incorporating engineering in K-12 education?

Any thing else you wanted to add or that you think would be really important to note in understanding how engineering currently fits in K-12 right now?

Appendix E: Kumu – Ecosystem Map Tool

For detailed information on how to use and update the Ecosystem Map tool (Kumu), please visit the following website https://docs.kumu.io/ and scroll through all the available functionalities using the left-sidebar. You can also use the search bar on the page's top-left-side to look for specific functionalities.

How to create connections using dividers (|):

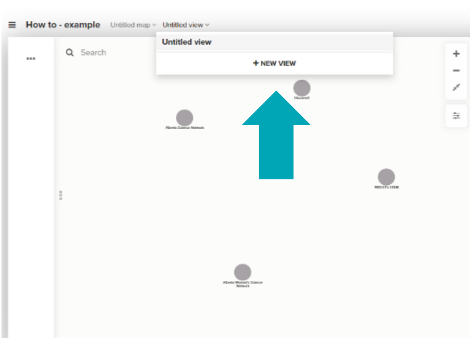
This section will cover how to create connections using dividers. Since the Ecosystem Map is linked to an external Google Spreadsheet[2], this section will assume all updates will be made using such a file.

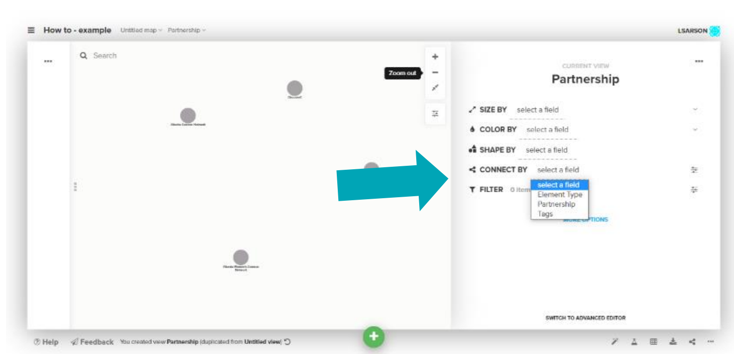
Dividers are used to group different information in a single column. As such, you can organize the Google Sheet so that multiple columns for the same category of items are not required as you can group all the data for that category in a single column by using dividers. For example, instead of having multiple columns named "Partner 1", "Partner 2", "Partner 3," you can organize your data as the example below:

Example: using dividers to group items of the same category in a single column

	A	B
1	Label	Partnership
2	Alberta Science Network	Engineers Canada | Let's Talk Science | Actua | Engineers of Tomorrow
3	Alberta Women's Science Network	Engineers Canada | Actua | Engineers of Tomorrow
4	WISEST's STEM	Engineers Canada | Actua | Let's Talk Science
5	DiscoverE	Engineers Canada | Let's Talk Science | Actua | Engineers of Tomorrow

Once you have filled your column with the information you need (in this case, partnership information), you need to create a view[3] on the Ecosystem Map[4]. To create a view: Click "New View" and then "Connect by partnership" (if you already have a view, jump to the "connect by" step.)

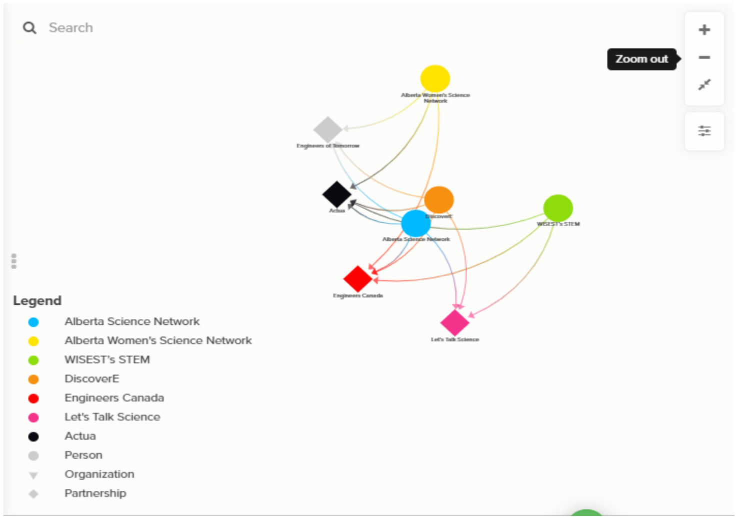




After following these steps, you should see an Ecosystem Map similar to the following:

---

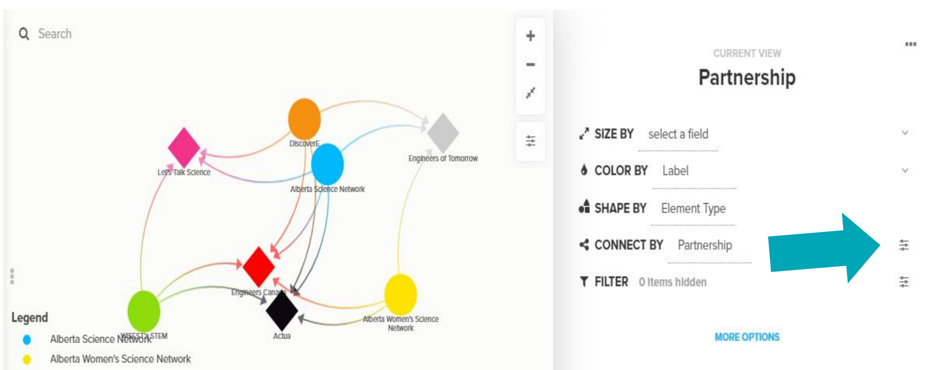
2 https://docs.google.com/spreadsheets/d/1El_Jzg4am3nu3VJgxJMusNst1hPlUfMZWC6TiEDGjnw/edit?usp=sharing
3 You only need to create a view for the first time you're including that category. Afterwards, you just need to update the already existing view to include new data.
4 Note: The Ecosystem Map page needs to be refreshed to incorporate changes made in the Google Spreadsheet file.



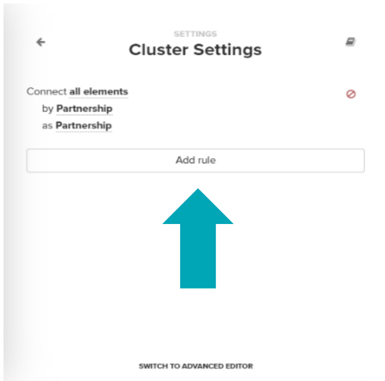
To add more connections based on different categories, create a new column on the Google Spreadsheet file. Below is an example of regional presence:

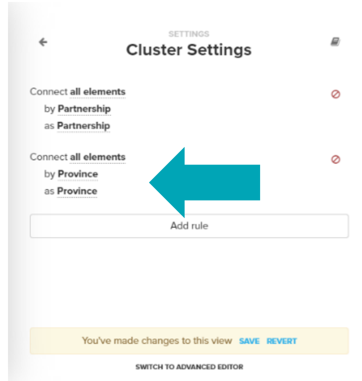
	A	B	C
1	Label	Partnership	Province
2	Alberta Science Network	Engineers Canada | Let's Talk Science | Actua | Engineers of Tomorrow	AB | SK | MB
3	Alberta Women's Science Network	Engineers Canada | Actua | Engineers of Tomorrow	AB | BC | SK
4	WISEST's STEM	Engineers Canada | Actua | Let's Talk Science	NL | MB | BC | National
5	DiscoverE	Engineers Canada | Let's Talk Science | Actua | Engineers of Tomorrow	NS | NL | NB | National

Click on the "settings" icon on the right side of "connect by."

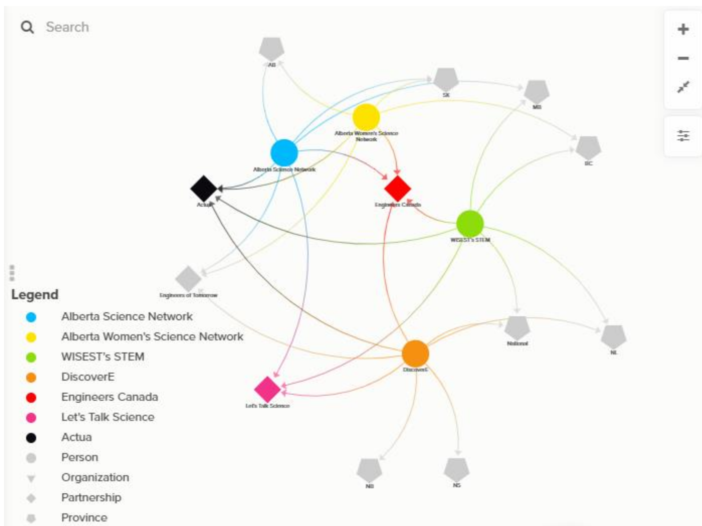


Click on "add rule" and then select "by province." Now you will have a map with connections by partnership and province. You can add multiple connections by following this method.





This should be your new map view.



Note: When new data is added to the spreadsheet, the Ecosystem Map on Kumu needs to be refreshed for the new data to be incorporated into the map.

Note 2: For the sake of the spreadsheet's and Ecosystem Map's organization, we **don't** recommend adding **different** categories to a single column using dividers. (e.g., mixing partnership and region data into a single column).

Appendix F – Curriculum Entry Requirements

PROGRAM	REQUIRED COURSES									MINIMUM ADMISSION AVG
University of British Columbia	English Studies 12 or English First Peoples 12	Pre-Calculus 12	Chemistry 12	Physics 12	Any English Language Arts 11 or any English First Peoples 11	A language 11 or waiver	Pre-Calculus 11 or Foundations of Mathematics 12	Chemistry 11	Physics 11	
University of Victoria	English Studies 12 or English First Peoples 12 (≥67%)	Pre-calculus 12 (≥73%)	Physics 12 or Chemistry 12	Approved academic 12	Approved English 11	Pre-calculus 11	Chemistry 11	Physics 11	Approved social studies 11/12	
Simon Fraser University	English 12	Mathematics 12	Physics 12	Chemistry 12	-	-	-	-	-	
University of Alberta	Math 30-1	Math 31	Chemistry 30	Physics 30	English 30-1	-	-	-	-	
University of Calgary	English Language Arts 30-1	Mathematics 30-1	Mathematics 31	Chemistry 30	Physics 30 or Biology 30	-	-	-	-	
University of Manitoba	English 40S	Pre-Calculus Mathematics 40S	Chemistry 40S	Physics 40S	-	-	-	-	-	
University of Saskatchewan	Chemistry 30	Physics 30	Pre-Calculus 30	-	-	-	-	-	-	
University of Regina	English Language Arts A30	English Language Arts B30	Pre-Calculus 30 or Calculus 30	Chemistry 30	Physics 30	-	-	-	-	
University of New Brunswick	English 122/Français 10411 (≥70%)	Pre-Calculus A 120/Mathématiques 30331C (≥70%)	Pre-Calculus B 120/Mathématiques 30411C (≥70%)	Chemistry 122/Chimie 52411 (≥70%)	Physics 122/Physique 51411 (≥70%)	One elective - Group 1, 2 or 4 (≥60%)	-	-	-	75%
Memorial University of Newfoundland	Strong marks in advanced mathematics	The appropriate mark in the Math Placement Test as administered by Memorial University	Strong marks in science	-	-	-	-	-	-	-
Acadia University	Precalculus 12 (≥60%)	Chemistry 12 (≥60%)	-	-	-	-	-	-	-	-
Cape Breton University	English 12	Math 12	2 Science 12	1 additional K 12 academic or advanced level course	-		-	-	-	65%
Dalhousie University	Academic English 12	Pre-calculus Math 12	Academic Chemistry 12	Academic Physics 12	One additional academic subject	-	-	-	-	70%
Saint Mary's University	English 121 or 122 (≥60%)	Pre-Calculus 12B; or Calculus 120 (≥60%)	Chemistry 121 or 122 (≥60%)	One academic 12 science course (Physics 121 or 122 recommended) (≥60%)	One additional academic 12 course (≥60%)	-	-	-	-	70%

PROGRAM	REQUIRED COURSES									MINIMUM ADMISSION AVG
Algoma University	ENG4U	MHF4U	SCH4U	SPH4U	1 additional 4U Science or Mathematics	1 additional 4U/M	-	-	-	70%
Carleton University	Advanced Functions (≥75%)	Chemistry (≥75%)	Physics (≥75%)	One credit from Biology, Calculus and Vectors or Earth and Space Science (≥75%)	-	-	-	-	-	75%
Lakehead University	6 G 12U or M courses	-	-	-	-	-	-	-	-	70%
McMaster University	ENG4U	MCV4U	SCH4U	SPH4U	-	-	-	-	-	-
Queens University	English 4U (>70%)	Calculus and Vectors 4U	Chemistry 4U	Physics 4U	Advanced Functions 4U	-	-	-	-	-
Ryerson University	English/anglais (ENG4U/EAE4U) (>70%)	Advanced Functions (MHF4U) (≥70%)	Calculus and Vectors (MCV4U) (≥70%)	Physics (SPH4U) (≥70%)	Chemistry (SCH4U) (≥70%)	-	-	-	-	70%
Trent University	SCH4U	SPH4U	MCV4U	ENG 4U (≥60%)	-	-	-	-	-	80%
Ontario Tech University	ENG4U	MHF4U	MCV4U	SCH4U	SPH4U	-	-	-	-	-
University of Ottawa	English 4U or Français 4U	Advanced Functions 4U	Calculus and Vectors 4U	Biology 4U	Chemistry 4U	Physics 4U	-	-	-	70%
University of Toronto	Advanced Functions (MHF4U)	Calculus & Vectors (MCV4U)	Chemistry (SCH4U)	English (ENG4U)	Physics (SPH4U)	-	-	-	-	-
University of Waterloo	Advanced Functions (>70%)	Calculus and Vectors (≥70%)	Chemistry (≥70%)	Physics (≥70%)	English (ENG4U) (≥70%)	-	-		-	80%
University of Western Ontario	English (ENG4U)	Chemistry (SCH4U)	Physics (SPH4U)	Advanced Functions (MHF4U)	Calculus and Vectors (MCV4U)	-	-	-	-	
University of Windsor	Advanced Functions/MHF4U (>74%)	Advanced Functions/MHF4U (≥74%)	Advanced Functions/MHF4U (≥74%)	English/ENG4U (≥74%).	-	-	-	-	-	-
York University	ENG4U (>70%)	SCH4U (≥70%)	SPH4U (≥70%)	MHF4U (≥70%)	MCV4U (≥70%)	-	-	-	-	-
University of Prince Edward Island	G12 academic English	G12 academic Mathematics (≥70%)	Two additional G12 academic Science subjects, chosen from Biology, Chemistry or Physics (≥60%)	One additional G12 academic course (≥60%)	-	-	-	-	-	70%

PROGRAM	REQUIRED COURSES									MINIMUM ADMISSION AVG
Concordia University	CHEM 101 or 202-NYA (≥60%)	MATH 103 or 201-NYA	203 or 201-NYB	105 or 201-NYC	PHYS 101 or 203 NYA	201 or 203 NYB	-	-	-	-
McGill	Chemistry NYA (00UL), 01Y6; Chemistry NYB (00UM)	Math NYA (00UN), 01Y1; Math NYB (00UP), 01Y2; Math NYC (00UQ), 01Y4;	Physics NYA (00UR), 01Y7; Physics NYB (00US), 01YF; Physics NYC (00UT), 01YG	-	-	-	-	-	-	-
Université Laval	Mathématiques NYA, NYB, NYC (ou 103-77, 203-77, 105-77)	Physique NYA, NYB, NYC (ou 101, 201, 301)	Chimie NYA (ou 101)	Biologie NYA (ou 301)	-	-	-	-	-	-

Appendix G – Collective Impact Approach

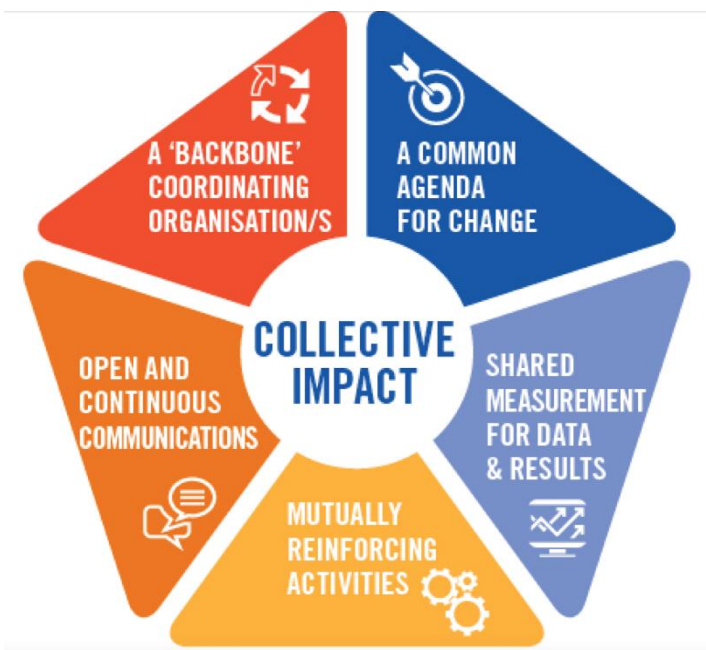
Collective Impact Model

Given that there is not a clear definition of engineering in the K-12 space and there is no leading influencer among the varied ecosystem of engineering organizations in Canada, this complex interplay of issues calls for structured collaboration and systems-level change. A collective impact model can foster widespread social change through cross-sector coordination rather than from individual organizations in isolation [29]. Exploring a collective impact model to help organize the multitude of stakeholders involved in engineering initiatives in Canada and set a shared agenda can help achieve goals that are too wide reaching for a single organization to influence alone.

Many of the challenges identified in this report align with the functions of the collective impact model framework. The five guiding principles for collective impact are a common agenda, shared measurement systems, mutually reinforcing activities, continuous communication, and a backbone support organization.

These principles provide a model for organizational interaction that leads to synchronized and emergent results. A shared agenda can harbour intentionality and enables all participating organizations across the engineering ecosystem to collectively envision a common goal. Shared measurement, mutually reinforcing activities and continuous communication enable accountability and facilitates an ecosystem of trust between participants [29]. Finally, the backbone organization supports the various cross-sector players to remain to adhered other common agendas and why it is important.

Below are the guiding principles of the collective impact model as it relates to addressing some of the key challenges identified in this report and the goal of promoting engineering in K-12.



1. Common agenda for change

All stakeholders within the ecosystem must agree to a common agenda. The collective impact approach calls for the myriad of participants to focus on a single common agenda. All organizations must have a common understanding of the problem and a mutual agreement on how to solve it [29].

As mentioned, engineering is being taught in the classroom, but students may not consider engineering as a path simply because it is not named or well-defined in the K-12 space. Educators also have difficulty teaching engineering due to a lack of understanding of the language and models used to incorporate engineering concepts into the classroom. This calls for a collaborative cross-sector approach that involves key participants in the Canadian engineering ecosystem.

Goals for change:

- **PROMOTE EXPLICIT INCLUSION OF ENGINEERING IN CURRICULUM ACROSS CANADA***:* Advocate for engineering to be explicitly identified in K-12 learning objectives or outcomes in all provincial curriculum
- **A FOCUS ON LANGUAGE:** Promote the increased use of the word engineering in the classroom and increase educator confidence by establishing and promoting simple-to-understand shared definition and messaging.

The resource *A Collective Impact Implementation Tool Box For Healthy Start* (2016) outlines factors to consider when working to build a common agenda. These include:

- Understanding the prior history of collaboration;
- Understanding what data are required and who has the data relevant to the issue;
- Understanding your community context (community system);
- Building a core group of interested individuals;
- Recruiting an influential organization to convene community conversations;
- Developing a broader community engagement strategy.

2. Shared Measurement Systems

The development of a shared measurement system is crucial to collective impact. This ensures that the efforts of all organizations remain in line with the common agenda, allows for participants to learn from each other, and functions to document the progress of the overall social project. Web-based technologies are commonly used to track results and data [29], enabling common systems for reporting performance and measuring outcomes that are credible, cost-effective, and efficient. For example, a collective impact case study of a network of preschool programs titled StriveTogether agreed to measure their results on the same criteria and use only evidence-based decision making (A Collective Impact Implementation Tool Box For Healthy Start, 2016). All organizations within this network engaged in the same type of activity report on the same measures. Looking at results across multiple organizations enables the participants to spot patterns, find solutions, and implement them rapidly.

Our findings suggest that existing K-12 student-based data about enrollment is very limited. As mentioned, the lack of consistent collection and availability of data makes it difficult to identify best practices to support K-12 goals and engagement in engineering and calls for the rigorous data collection inherent to collective impact.

Goals for change:

- **ESTABLISH A MECHANISM TO GATHER AND UTILIZE SHARED DATA:**
    - Advocate for access to a shared provincial enrollment database for K-12 students at the student level to track progress – only data necessary to determine if a student meets current requirements for entry into post-secondary engineering programs would be needed. This data would allow objective measurement in promoting the pursuit of engineering as a career path.
    - Identify shared performance indicators for key initiatives & organizations to support program measurement and encourage data sharing

The resource *A Collective Impact Implementation Tool Box For Healthy Start* (2016) outlines factors to consider when designing a shared measurement system. These include:

- Work with key participants in your Collective Impact effort to identify the specific benefits or changes you want to monitor.
- Educate all partners on the outcomes you want to track and the importance of providing as much detail as possible regarding numbers, dates, and/or results, and agree on a tracking schedule (weekly, monthly, etc.)
- Establish a process or system to send out requests to all partners for their data entries as agreed, and consolidate results received into a spreadsheet.
- Develop “Results Reports” that summarize the data from the data entries and share it regularly with key partners and community members.

3. Mutually Reinforcing Activities

Mutually reinforcing cross-sectoral coordination is fundamental to the success of collective impact. The interplay of participants must be strategically coordinated, as activities among organizations involved in collective impact are differentiated but align with the common agenda: *“collective impact initiatives depend on a diverse group of stakeholders working together, not by requiring that all participants do the same thing, but by encouraging each participant to undertake the specific set of activities at which it excels in a way that supports and is coordinated with the actions of others”* [29].

For example, all participants in the Elizabeth River Project agreed to a common agenda - an 18-point watershed restoration plan. However, each participating organization plays a different role based on their resources and competencies. In this case, one group of organizations focuses on citizen engagement and grassroots support, while another concentrates on the recruitment for industrial participants who voluntarily reduce pollution [29].

The ecosystem map provided as a part of this work can function as a tool for developing a collective impact strategy and curating mutually reinforcing activities that align with the larger project. The ecosystem map supports the project of undertaking mutually reinforcing activities by providing a map of existing stakeholders and organizations and the resources and tools they provide. This will promote collaboration, maximize resources, reduce duplication of work and help move the larger agenda forward.

4. Continuous Communication

Building trust among participants requires consistent communication. Proving the common motivation behind each organization's differentiated effort in addressing the common agenda necessitates regular communication and is necessary for showing that the interest of each participating organization is inherent to the common agenda.

Kania and Kramer, seminal researchers in the field of collective impact, note that *"all the collective impact initiatives we have studied held monthly or even biweekly in-person meetings among the organizations' CEO-level leaders. Skipping meetings or sending lower-level delegates was not acceptable. Most of the meetings were supported by external facilitators and followed a structured agenda"* [29].

5. Backbone Support Organization

The management of collective impact requires a separate organization to serve as the backbone for the entire social project. Coordination takes time, and none of the participating organizations has any to spare. The backbone organization does not authorize what practices each of the multitude of participating organizations should pursue—rather each organization and network is free to chart its course consistent with the common agenda and informed by the shared measurement of results. The role of the backbone organization is to create urgency, mediate conflict among stakeholders, and provide a clear vision to stakeholders of what success looks like and why the initiative is worth undertaking [29]. The backbone organization also functions to provide resources to stakeholders to ensure that the common agenda, shared measures, and implementation strategy is supported and understood by the entire collective.

Goals for change:

- Explore possible organizations to serve as the backbone organization in the system.

To ensure credibility, the backbone organization as the supporting infrastructure requires the following considerations:

- Do stakeholders perceive the organization as an effective backbone?
- If the organization took on this role would the other organizations have a negative or positive reaction? Would this organization be supported?
- What are the current strengths and weaknesses within the organization that may affect its capacity to being the infrastructural backbone?