# Creating Equity-Focused STEM Learning Programs with k2i academy

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## Abstract

*k2i (kindergarten to industry) academy within the Lassonde School of Engineering at York University works to meaningfully design and integrate equity and inclusion based science, technology, engineering and math (STEM) programs into all areas of education. These programs address systemic barriers that limit youth from succeeding in STEM areas, pursuing further education and finding a place in industry. The Bringing STEM to Life: Work-Integrated Learning program was designed to address inequities for underrepresented high school students by offering a high school physics credit during the summer in addition to a paid position as a Lab Assistant collaborating with Lassonde Faculty researchers and industry partners. k2i academy partners with school boards in the greater Toronto area to identify Women, Black and Indigenous students within their communities to participate in the experience. The educators, faculty researchers and undergraduate mentors who facilitate the work collaborate to create culturally relevant curriculum that builds skills in engineering design, coding and computational thinking with a focus on sustainability through the use of the United Nations Sustainable Development Goals.*

**Keywords:** K-12 Education, STEM Outreach, STEM Education, Engineering Education, Equity Diversity and Inclusion, K-12 Outreach

## Introduction

The k2i academy at the Lassonde School of Engineering - York University works with K-12 education sector partners to design and implement programs that address systemic barriers to opportunities in STEM. In 2019, the Ontario Network of Women in Engineering reported that 24.4% of undergraduate engineering students were women. (ONWiE, 2019) In 2016, Engineers Canada reported that only 1% of undergraduate engineering students enrolled in accredited engineering programs identified as Indigenous peoples. (Engineers Canada, 2016) In this paper, we will share our experience in designing a program that addresses some of the challenges that students and families may encounter and describe the innovative program that reconnects high school students to reconsider possibilities in STEM post-secondary pathways. The *Bringing STEM to Life: Work-Integrated Learning* program was designed to address possible barriers to opportunity while creating a learning environment that seeks to foster curiosity, bring physics concepts to life, and develop their professional skills.

The k2i academy approaches the design of youth STEM programs by considering the experiences of students and the potential systemic structures that may have impacted access to opportunities. k2i academy works with K-12 education sector partners to build programs that are accessible for students who are traditionally not engaging in STEM outreach programs. In order to increase diversity in STEM, we must work on addressing the inequities that have persisted in our educational system, and work with partners in innovative ways to co-design and co-implement programs that acknowledge, identify and foster the talent and skills of youth.

**Literature Review**

In Ontario, Canada, science is compulsory until grade 10, making the choice to pursue physics, chemistry, biology or earth and space science optional in grade 11 and 12. In order to pursue post-secondary programs in STEM, students must graduate with 2 science courses in grade 12 which requires grade 11 prerequisite courses in the same science courses. (Government of Ontario, 2020) Additional prerequisite requirements include senior mathematics courses and english. A student's decision to continue their studies in science and math beyond the minimum requirements is driven by many factors including student interest, previous experiences, and family influences. The K-12 education system continues to have inequities which have resulted in fewer students of various genders, socioeconomic and ethno-cultural backgrounds from enrolling in the prerequisite courses necessary for post-secondary studies in STEM. (Saw et al.,2018; Wells, 2018) In a report published by Dr. C. James at York University, found that in the Toronto District School Board, 69% of Black students graduate from high school compared to 84% white students and 87% of other racialized students. He also reported that though 81% of white students and 80% of other racialized students were in academic programs leading to university programs, only 53% of Black students were in academic programs. (James, 2017) Robson et al. (2018) conducted a study where they looked at educational pathways with a small cohort of students from the Toronto District School Board.The study found that black and latino students were over represented in applied streams and had lower marks on, attributed to early life disadvantages present in elementary school or earlier that impacts their opportunity for post-secondary education. (Robson et al., 2018) According to Engineers Canada, 17.9% of licensed engineers in Canada are women. (Engineers Canada, 2020)

In Canada, more than 4.9 percent of the total Canadian population identify as Indigenous peoples (Statistics Canada, 2016), however, only 0.6 percent of undergraduate engineering students enrolled in accredited engineering programs in Canada identify as Indigenous peoples (Engineers Canada, 2020). This is not representative of our society. According to the report on Indigenous Peoples' Access to Post-Secondary Engineering Programs, factors such as unemployment, poverty, insufficient access to prerequisite STEM courses in high school education, and limited information about career opportunities are all factors that contribute to the challenges. (Ricci, 2016) Statistics Canada reports that 29 percent of Indigenous peoples in Canada do not graduate high school. (Statistics Canada, 2013)

According to Engineers Canada, in 2020, 24.2 percent of undergraduate enrolment in engineering programs were women with the highest proportion in biosystems programs (53.1 percent), chemical engineering (42.2 percent), and geological engineering (37.4%). (Engineers Canada, 2020) The largest gender gap in STEM enrolment lies in computer science, engineering, mathematics, physics, chemistry, and other math-intensive fields with 24.2 percent of men enrolled in these programs compared to 5.4% women. (Chan et. al, 2021)

The challenge we face to diversify participation in post-secondary STEM programs starts early. With women "leaking out of the pipeline" from high school into post-secondary engineering programs (Wells, 2018) and with low graduation rates for Black and Indigneous youth from high school, it is not surprising to have challenges.

Engaging in STEM enrichment opportunities often inspires students to consider pursuing post-secondary studies in STEM. However, the ability to access enrichment programs that

are outside the school day often requires additional resources and flexible time that enables the students to participate as well as a knowledge that these programs are offered. (DeCoito, 2016) For some students, competing priorities including family obligations, financial challenges, or competing interests in other activities such as sports and music, may prevent them from participating in a STEM outreach program. Access to enrichment STEM programs may also require application processes that rely on traditional metrics for success, including transcripts and recommendation letters. At times, enrichment opportunities that are offered by post-secondary institutions may require on campus engagements. Geographic proximity to programs often limits participation.

Student knowledge and perception of STEM careers and STEM pathways may also influence their decisions. Students and their families may not have access to networks that can provide guidance, mentorship, and coaching that may help students to make more informed decisions about their future.

STEM leadership development is an important component of the program. Providing an opportunity to strengthen understanding of STEM education and the critical role that we all play within the education system will enable program development that addresses inequities in STEM education.

How might we create equitable STEM programs that address systemic barriers to opportunities for underrepresented students in STEM?

One way k2i academy has responded to this question and addresses systemic barriers to STEM opportunities is through the *Bringing STEM to Life: Work Integrated Learning* program that provides underrepresented youth with the opportunity to engage in a paid work experience with Lassonde School of Engineering students, faculty and staff while earning a physics credit towards their Ontario high school diploma.

This paper will provide an overview of the design and implementation methods k2i academy considered when constructing the program, review and discuss the results from previous iterations of the program, and will conclude with addressing successes, challenges and next steps for future iterations.

## Design and Implementation Methods

The *Bringing STEM to Life: Work Integrated Learning* program was intentionally designed to address systemic barriers high school students face, specifically underrepresented youth as they move through the education system and into possible STEM career pathways. The program engaged with students who just completed grade 10 during the school year. Students who did not elect to continue in science courses were encouraged to consider this opportunity during the summer. The program considered socioeconomic barriers for students, often choosing between work and school by combining 140 hours of paid work, hired as *Lab Assistants*, with a course credit in either grade 11 university physics or grade 12 college physics. As students in Ontario are currently streamed in grade 10, it was important for this program to consider students who are in both academic and applied streams. The successful completion of either course would open up options that bring them closer to having access to STEM programs within colleges or universities. The summer program did not have an application process as these processes can often filter out deserving applicants,

instead, school boards worked with school communities to identify students who would most benefit from this experience. To provide access to youth from all over the greater Toronto area, the program ran virtually, to eliminate the barrier of geographic location and inability to get to York University campus. Table 1 outlines the barriers to opportunity that were identified and the program interventions designed to address these barriers.

**Table 1: Systemic Barriers and Interventions**

| Barriers to Opportunity | Program Interventions |
|---|---|
| Application process to STEM outreach programs | Remove the application process and allocate positions based on need |
| Students may have to choose between paid work and learning opportunities | Provide a work integrated learning experience where students can receive a paid work opportunity while also working towards a course credit |
| Not being able to afford enrichment STEM outreach programs | Remove the financial barrier to the program |
| Students have already decided not to pursue STEM and are not enrolling in prerequisite courses such as physics | Offer a high school physics credit program and admit students who have already opted out of additional science programs |
| No role models or access to mentors | Provide access to mentors from diverse backgrounds who can support students throughout the program |
| No networks to provide advice for post-secondary studies | Have undergraduate mentors, research faculty and additional leaders provide insights and advice on post-secondary studies |
| Geographically living in a community that is distant from a post-secondary institution | Provide the program virtually to allow students from diverse geographical locations to participate |

**Curriculum Design**

The content for the program required the integration of the Ontario physics curriculum and the research and engineering project that all high school students were required to complete during their employment. The program was a blend of project-based learning, inquiry-based learning, and direct instruction with a focus on skill development, construction and application of knowledge, confidence building and strengthening engagement through hands-on learning. The curriculum design included building learning experiences that are culturally relevant and included new skills that are traditionally not included in physics courses in Ontario, including coding, computational thinking, and engineering design. The curriculum in the program provided content knowledge while also deepening technical skills, better preparing high school students with the skills required to succeed in their future careers. To create interest and agency for STEM learning, the program curriculum was designed to connect to the United Nations Sustainable Development Goals (UNSDGs) and

encouraged high school students to identify a local problem that connects to the themes in the UNSDGs that they wish to tackle for their research and engineering project. Students learned about the role and responsibility of STEM professionals in addressing societal challenges through the projects they developed.

The Ontario physics course was delivered by Ontario licensed secondary teachers from our partnering school boards, ensuring that all course requirements are met in alignment with the Ontario Ministry of Education curriculum policy. Components of the physics course were designed and delivered by the physics teacher, while opportunities for cross-collaboration on physics activities and project work were integrated into the curricular design for the overall experience. Equipment and materials for all physics course related activities and projects were customized, packaged and delivered to each student, teacher, and mentor to enable online, hands-on interactions and learning experiences.

The research and engineering projects were led and facilitated by the k2i academy undergraduate mentors who were hired for the summer to design learning experiences that support the high school lab assistants. A team of Lassonde School of Engineering research faculty advisors worked closely with the undergraduate mentors to co-develop the projects, including timelines and milestones, to ensure that each high school lab assistant is set up for success. The overall experience focused on process and included opportunities for rehearsals, feedback, and ongoing enhancements. The projects required a final presentation to be delivered in a virtual conference at the completion of the program.

The undergraduate mentors were an integral component of the curriculum design. They worked daily with the high school lab assistants and developed working relationships that supported student success through tutoring of physics course content, ongoing guidance on projects and designing additional activities to further develop skills and areas of knowledge.

**STEM Leadership**

The *Bringing STEM to Life: Work Integrated Learning* program also works to address issues around STEM leadership by constructing work embedded professional learning opportunities for the undergraduate mentors, faculty members and high school physics teachers.

Undergraduate mentors consist of current or recently graduated university students in a STEM area of study who are responsible for mentoring the high school lab assistants during their 140 hours of work. Mentors supplement learning happening in the classroom through hands-on activities that further develop learning in engineering design, electronics, coding and computational thinking as well as supporting research and engineering projects. Through this role, undergraduate mentors develop critical skills for success in future roles in STEM fields such as technical skill development, improved communication, teamwork, project management, facilitation and collaboration as well as relevant work experience. The mentor role is intentionally designed to foster leadership in underrepresented undergraduate students and to provide diverse role models for high school lab assistants. The k2i academy undergraduate mentor is provided with professional learning and development through workshops, networking opportunities, and ongoing support as they pursue their own post-secondary studies and career aspirations.

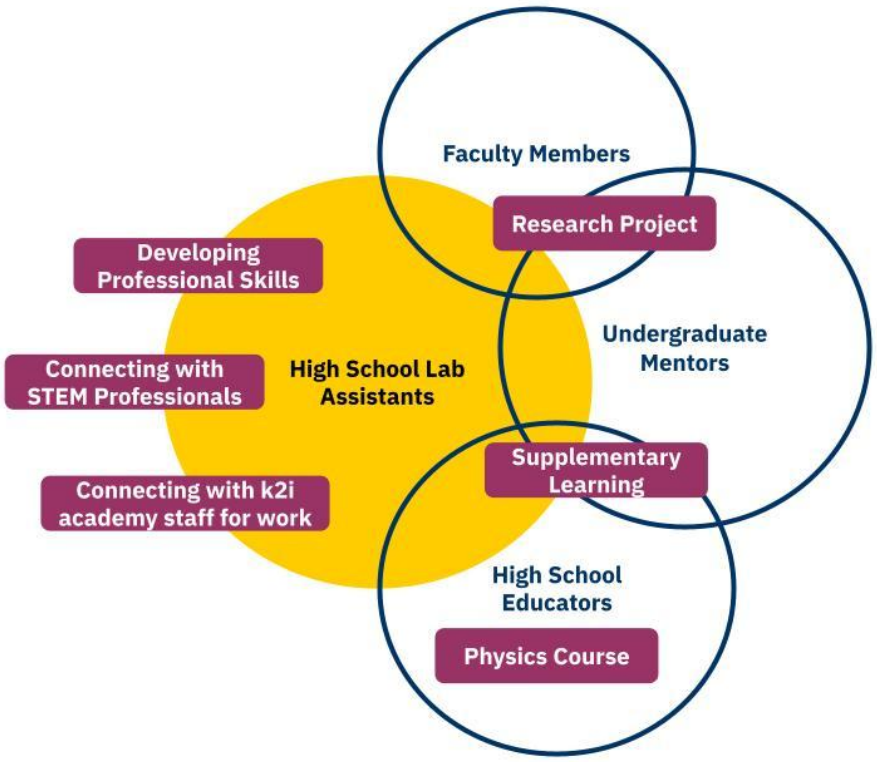
Faculty members from various departments within the Lassonde School of Engineering participated in the design of the research and engineering projects for the program. Research faculty worked closely with the k2i undergraduate mentors to co-create a program

for the high school lab assistants. Faculty members obtained insights into the K-12 education system, gained better understanding of student experiences, and had an opportunity to mentor and advise undergraduate students.

The physics educators developed and delivered the physics course in alignment with the Ontario physics curriculum policy. They were responsible for developing and delivering lessons, assessing and evaluating student achievement, and working with the k2i academy staff and undergraduate mentors for integrating the project components into the course requirement. Through the program, the teachers had opportunities to develop new technical skills through the emphasis of hands-on learning that incorporated electronics, coding and engineering design. The physics teachers also gained system level insights into the barriers youth face in pursuing a STEM career pathway and had opportunities to network and collaborate with k2i academy, research faculty, STEM professionals, and physics teachers from different K-12 school boards.

The overall interactions between the high school lab assistants, undergraduate mentors, and research faculty is illustrated in Figure 1.

**Figure 1: The Roles and Interactions**




The lab assistant experience involved interactions with their high school teacher, research faculty, undergraduate mentors and k2i academy staff. The interactions between the different roles provided each high school lab assistant with opportunities for learning and support to successfully deliver on the outcomes of the program - successful completion of the research and engineering project and earning their high school physics credit while also engaging in opportunities that might excite their interest in STEM pathways.

## Results and Discussion

In Summer 2021, the *Bringing STEM to Life: Work-Integrated Learning* program ran in partnership with Peel District School Board, Toronto District School Board and York Region District School Board to provide 90 youth with a position as Lab Assistant for a 5 week period. School boards prioritized underrepresented students in STEM and considered socioeconomic factors for participation in the program. Student achievement was not a factor in the selection process. The high school lab assistants received 140 hours of paid work and participated in 175 hours of learning towards either a grade 11 university physics credit or a grade 12 college physics credit. The program consisted of 86% self identified girls, 28% self-identified black youth and 4% self-identified Indigneous youth. At the completion of the program, 98% of youth obtained their physics credit with a course median of 85% in grade 11 university physics and a median of 87% in grade 12 college physics.

The work portion of the program was predominately supported by 24 undergraduate mentors currently enrolled or recently graduated from a STEM area of study. The mentors consisted of 83% visible minorities and 71% women in STEM. In addition to undergraduate mentors, 9 Lassonde School of Engineering faculty members supported the design and implementation of the research and engineering projects. The program included 4 high school physics educators from various partnering K-12 school boards who delivered the Ontario physics curriculum aspects of the program and worked closely with high school students towards earning their high school credit upon completion of the program.

Participants in the *Bringing STEM to Life: Work-Integrated Learning* program have shared their experiences throughout the program through ongoing conversations, discussions, and pre and post surveys. A few of the comments shared by participants include:

“The most powerful learning moment was seeing that there were other girls who look like me who are as interested in STEM as I am.” - High School Lab Assistant

“My most powerful learning moments were having the opportunity to do hands-on experiences to deepen my understanding of what I'm learning in class.” - High School Lab Assistant

“The most memorable moment would be connecting with my peers and mentors.” - High School Lab Assistant

“I feel like I'm ready to participate more in class and be more open to sharing my ideas.” - High School Lab Assistant

“This program helped me to have another point of view on every concept that I learn at school. we always are taught with formulas and memorizing rules and no one ever tries to connect them in real life and their importance in real life.” - High School Lab Assistant

“The experience really helped me identify what makes an effective teacher, what makes students learn. I would say it’s the perfect storm for optimal learning.” - Physics Educator

“My key takeaway is that anyone can learn anything, the age, religion, colour of skin, nothing matters as long as you are willing to learn and put in the work, you can do anything.” - Undergraduate Mentor

“Our Lab Assistants showed how engineering, science and technology can bring UN Sustainable Development Goals to reality. This is just the beginning of your journey. I’m very optimistic and certain the future is in good hands.” - Faculty Member

The high school participants share their sense of belonging when they see others who are like them working with them. The hands-on learning experiences, connected to real world contexts, strengthens their understanding of concepts and creates a connection that makes lasting impressions. The high school participants also highlight the importance of connecting with peers and mentors and creating a learning environment that encourages participation and helps students to build a sense of self and confidence to engage in learning. In addition to the high school student experiences, this program also highlights the impact on physics educators, undergraduate mentors and research faculty. In addition to the high school student outcomes, the program creates an opportunity to transform how educators imagine teaching and learning for high school students, empowers undergraduate mentors to create change by supporting youth, and creates optimism for the future where more diverse students will pursue STEM career pathways and create solutions to complex societal challenges.

## Conclusions

The *Bringing STEM to Life: Work-Integrated Learning* program has been successful in its approach to design and creating more accessible opportunities in STEM for youth. k2i academy and the Lassonde School of Engineering places equity, diversity and inclusion at the center of our work to ensure that programming reaches and supports youth of diverse backgrounds and experiences. The unique large-scale collaboration across the education sector including post-secondary educators, secondary educators, school board leaders and administrators, undergraduate students, high school students and industry professionals created an opportunity to consider multiple factors to address inequities to opportunity in STEM. The cross-sectionality of the program allows for the flow of information and learning between institutions and partners that would not otherwise occur and enables a collaborative process that co-creates a more robust program for youth. The multi-sector collaboration allows all participants to develop a deeper understanding of the current education system and creates opportunities for learning that go beyond the traditional norms of institutional structures.

Though the program has been designed to address barriers to opportunity, there are some key limitations to the program. The first limitation is the reach of the program. In summer 2021, three greater Toronto area schools participated in the program limiting the reach to only Ontario communities near urban areas. In the near future, k2i will be expanding the program to reach a northern Ontario school board but there is a need to continue this expansion to more communities within Ontario and beyond. Another limitation of the program is the navigation of different organizational structures, such as school boards and government, to optimize collaboration amongst institutional and organization leaders. Though the diversity of the groups involved in the design of this program is one of its greatest strengths, it does bring about operational challenges as each institutional structure

has their own systemic structures that k2i academy must consider as we build, problem solve, and implement programs of this scale. Lastly, another key limitation is the cost of design and delivery of this program. To scale this program to reach more high school students, it requires an investment in the infrastructure required to work differently with stakeholders and partners, the funds to be able to hire high school lab assistants and mentors, and the resources to be able to design programs that are hands-on, equipped with the equipment and materials for all participants to engage with.

k2i academy is currently making enhancements and preparing to implement the *Bringing STEM to Life: Work-Integrated Learning* program in summer 2022. The new iteration will expand the program to additional school boards in Ontario, remain as a fully virtual program, and strengthen our partnerships with collaborative partners to design a program that builds on the successes of the previous program. k2i academy is in a constant state of learning and development as we collaborate with new partners, communities and youth to ensure the programs remain relevant, sustainable and impactful. The importance of program design to be culturally relevant for learners is an important component of the work. (Wiseman et. al., 2019) Beyond this summer, the next steps include expanding the reach of the program to work with more school boards across Ontario, develop a study that more intentionally measures the impact of the program, continue to find ways to make enhancements to enable sustainability and strengthen partnerships with organizations and institutions to co-create programs that meets the needs of diverse learners. To further measure the impact of this program, k2i academy will reconnect with high school lab assistants as they continue in their high school studies to learn how this program may have impacted their interests in considering a STEM post-secondary pathway.

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