k2i academy: An Innovative Ecosystem Addressing System Barriers in STEM from Kindergarten to Industry

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Abstract – *k2i (kindergarten to industry) academy within the Lassonde School of Engineering at York University is an innovative ecosystem that works to meaningfully design and integrate equity and inclusion based STEM programs that address persistent problems in education. In order to address these barriers, k2i academy has developed an Inclusive Design Framework that guides our work and ensures that our programs are designed with equity, diversity and inclusion as the central principle. This framework was implemented in the Bringing STEM to Life: Work Integrated Learning program to address inequities for underrepresented high school students. The program participants earned a high school physics credit during the summer while gaining employment experience as a Lab Assistant working on projects with mentors. Through collaborations with Lassonde Faculty researchers, industry partners, and educational leaders in school boards, the program identified that these experiences allowed youth and K-12 educators to broaden their understanding of STEM, developed critical technical and professional skills and enabled youth to imagine and see themselves in a STEM career.*

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

1. Introduction

1.1. Background and Context

The k2i (kindergarten to industry) academy within the Lassonde School of Engineering at York University is an innovative ecosystem of science, technology, engineering, and mathematics (STEM) educators from both the K-12 and post-secondary sectors, thought leaders (such school board Directors, Superintendents, and leaders of community organizations) and organizational partners (such as District School Boards, professional STEM organizations, and industry) that work dynamically to identify systemic barriers to opportunity in STEM and create innovative solutions to break down these barriers.

Canada needs diverse STEM-ready problem solvers and innovators to tackle complex societal problems. Despite the efforts of many non-profit organizations and post-secondary institutions, engineering outreach programs have not made the large systemic impact we need that results in equitable outcomes for underrepresented people in STEM. Though STEM outreach programs have been life changing experiences for some, they continue to struggle to provide equitable opportunities for all youth. Equitable outcomes require recognition that experiences and circumstances are different for some and therefore, a commitment to resources and creating opportunities that meet the unique needs of some must be made. Designing more outside the school day STEM outreach programs that reach more youth may be part of the solution but we cannot ignore that youth spend a large part of their lives in formal education and therefore we must also work within the public school system, which we term K-12 education. K-12 education continues to seek out solutions to persistent challenges in providing more equitable outcomes for students and plays a critical role in designing future models to address systemic and institutional barriers to opportunity. As we learn to work intentionally together, we must consider factors such as gender and racial disparities in society, lack of access due to socioeconomic factors, insufficient Canadian equity-based data to guide strategies, and institutional processes and policies that make collaboration across organizations challenging.

This paper presents an integrated framework for STEM Outreach organizations to consider as we create an ecosystem for social justice in education.

1.2. Inequalities in Canadian STEM Education

STEM education and the STEM workforce continues to struggle with diversity. Men are twice as likely as

women to work in STEM outside of biology, there is underrepresentation of domestic Black youth in post-secondary programs, and only 4% of Indigenous youth pursue STEM education [1]. In a 2017 report, Dr. Carl James, the Jean Augustine Chair in Education, Community & Diaspora at York University reported that 84% of White students in the Toronto District School Board (TDSB) graduated from high school at the end of 5 years compared to 69% of Black students and 87% for other racialized students in the same cohort. The report also indicated that only 25% of Black students applied and accepted offers to university programs compared to 47% of White students [2]. In 2016, 94% of Black youth in Canada aged 15-25 said they would like to get a bachelor's degree or higher but only 60% thought they could [3].

The Leaky Pipeline is a metaphor often used to describe the journey for underrepresented people in STEM where at each stage of education people are leaking from the pipeline. However, the pipeline is not simply leaky where people passively fall out of the pipeline, rather, people are pumped and filtered out from the system due to systemic barriers along a person's educational journey, [4] with a significant lower rate of enrollment into selective science courses, specifically in grade 11 and 12 physics [5] beyond the compulsory grade 10 science courses in Ontario. Despite women representing half of the population, less than 20% of undergraduate students in engineering are women and only 13% of women are licensed engineers [5]. This situation is also compounded when identity is considered. Identity is more complex than binary gender and the intersectionality of identities, such as women of colour, specifically Black and Indigenous women, may have impacts that must be considered in educational experiences [6].

The socio economic status (SES) of youth also impacts experiences and circumstances that may affect interest in STEM. Saw et al. conducted a study that looked at high school students in the United States and the impact of intersectionality of race, gender and SES on STEM career aspirations [7]. The results showed that girls of all racial backgrounds and boys from Black and hispanic backgrounds had lower interest rates than the average and significantly lower interest when combined with low SES. Black low SES girls had the lowest interest rates among all demographics [7]. Low interest in STEM is a symptom of oppressive systems within society that has filtered and pushed certain individuals away from pursuing STEM and STEM-related fields early in their educational journey. The symptoms we describe here are intersectional and are experienced in complex ways.

Despite some insightful studies in America, a large portion of the current research on inequalities in STEM education within Canada solely focuses on the gender gaps, leaving underrepresented groups such as Black and Indigenous youth out of the narrative for change due to the lack of race based data that is collected within education systems [8]. In relation to general education pathways, Robson et al. conducted a study with a small cohort of students from the Toronto District School Board in relation to post secondary education transitions for youth in 2006 compared to 2011. The study concluded that Black and Latino students were more likely to be identified as having a special education need, were over represented in applied streams and had lower marks on average [9]. Robson et al. attributed these findings to early life disadvantages present in elementary school or earlier that impacts their opportunity for post-secondary education [9].

1.3. Current Progress to Address Barriers for Underrepresented Youth in STEM

Research in this area has identified factors that contribute to equity-deserving students pursuing STEM. One factor that is consistent within literature is the presence of mentors or role models that reflect the personal and social identity of the student through sources such as media and in person engagement [10]. DeCoito compiled a knowledge synthesis of current STEM initiatives within Canada determining that despite numerous post-secondary based programs that provide K-12 programming, there is a lack of research focused on the impact and outcomes of these programs as well as a lack of community knowledge that these programs exist [11]. Burke et al. specifically looked at K-12 based outreach programs in a post-secondary institution that engages with Black youth. It was determined that the programs were unable to address the whiteness that perpetuates post secondary institutions and lacked institutional funding to allow outreach programs to be sustainable within the community [12]. This indicates that despite efforts to provide positive STEM experiences for underrepresented youth, there are systemic challenges that continue to perpetuate a narrative where equity-deserving groups are not welcome within STEM.

1.4. Approaches to Equity Frameworks

Various frameworks have been used to approach equity in diverse settings as well as some specifically within STEM Education. In this paper we present a sample that represents a system or organizational approach to addressing equity. A framework by Madkins and Morton addresses anti-Blackness in the classroom and focuses on

shifting learning features such as participation structures that link to cultural identity and lived experiences, as well as linking STEM concepts to social justice to disrupt classroom practices [13]. The Equity-Oriented STEM Literacy Framework by Jackson et al. seeks to strengthen STEM literacy and build a culture where all students develop a sense of belonging within STEM to impart societal change and justice. Some key aspects of this framework are STEM identity development, empowerment, empathy, as well as critical thinking and problem solving [14]. Though STEM literacy is one component of the work, a framework that moves STEM education towards social and environmental justice requires a shift from STEM literacy to agential literacy - a framework that moves STEM outreach programs from empowerment to responsibility [15].

The Ontario Health's Equity, Inclusion, Diversity and Anti-Racism Framework developed by Corpus Sanchez International was created in response to inequities within health care. This framework has key considerations including, the importance of including people within the process, focusing on reducing disparities, addressing racism, and strengthening accountability by reporting and evaluating [16].

York University has two frameworks, *The Indigenous Framework for York University: A Guide to Action*, and *The Addressing Anti-Black Racism: A Framework on Black Inclusion*. Both frameworks focus on creating representation from each group within the University community through a commitment to data collection and research to better address inequities, alignment of policy and strengthening resources and spaces for communities[17][18].

The *Inclusive Design* framework plays a key role in designing inclusive programs in education. Chanicka and Logan identify how inclusive design can be used to promote equity and anti-oppression within education [19]. Some critical elements to consider when practicing inclusive design are building relationships with families, elders and communities, building leadership, analyzing data and representing student voice.

The k2i academy recognizes the complexity of this work. In this paper, k2i academy will share a framework that has emerged as a result of the programs we have been designing with our sector partners that integrates elements of the frameworks presented above. The k2i Inclusive Design Framework enables all participants within the ecosystem to better operate together to design and implement programs that address systemic barriers to opportunity in STEM.

2. The k2i academy Inclusive Design Framework

2.1. Application of Inclusive Design

The k2i academy Inclusive Design Framework integrates the work of Chanicka, J., & Logan, C. (2021), an approach to designing and implementing educational programs that is equity-focused, and creates opportunity for system change in the K-12 public sector, with an operational framework for program design within a STEM context. The framework incorporates the work of Chanicka, J., & Logan, C. (2021), and places students at the center of design, recognizing the unique experiences and circumstances of students and families, and operates to create wraparound, impact driven, intentional programs that are implemented in an integrated, multi-faceted approach that seeks to address symptoms of systemic oppression. The application of critical theory, anti-oppression theory and anti-racism education within this framework provides guidance and focus to ensure that initiatives are intentionally designed. The k2i academy Inclusive Design Framework also considers implementation at the individual, instructional and institutional level [19] to build high impact initiatives that begin the work towards a more inclusive educational system with equitable outcomes in STEM.

Figure 1 illustrates the k2i academy Inclusive Design Framework that provides an integrated approach to designing and implementing programs. The framework places students and families at the center and recognizes the intrapersonal experience and circumstances, including social location, abilities, languages, cultures, families, identities and social location, identified in the layer surrounding the student, that must be considered in the design. To design an inclusive program, the experiences of participants must be considered, represented and validated. The following layer represents the interpersonal experience and the aspects that must be developed with collaborators, partners, stakeholders and members of the community. These components allow for a deeper understanding of students and families, and their intrapersonal experience which will then inform work within the operational framework to be described in section 2.2.

The k2i academy Inclusive Design Framework is guided by three theories that are central to the inclusive design: Critical Theory, Anti-Oppression Theory and Anti-Racism Education. Critical theory may be used as an approach to evaluate, reflect, and critically think about

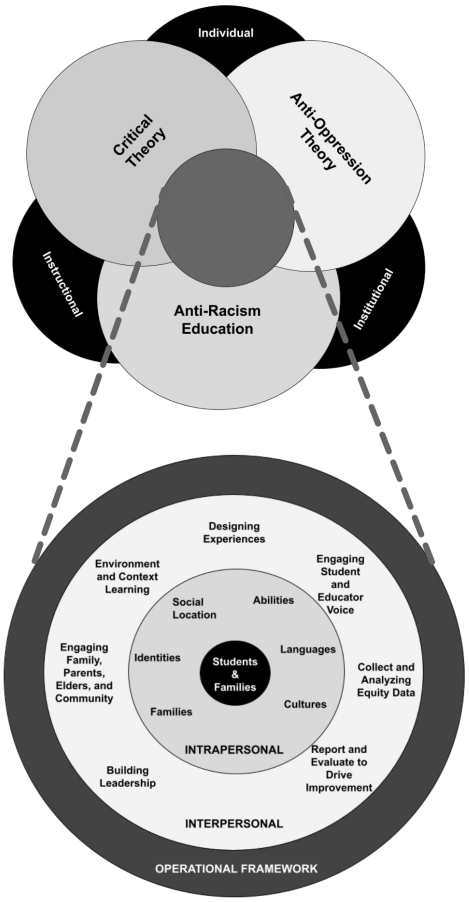

Figure 1: k2i academy Inclusive Design Framework

society and culture, to reveal how structures impact certain individuals, and to challenge power structures to create more equitable outcomes. k2i academy utilizes critical theory to identify areas of opportunity where barriers may be impacting youth, to report and evaluate structures to drive social impact, and to include and engage voices of underrepresented groups when approaching inclusive design. Anti-Oppression Theory looks at how systems of oppression such as colonialism, racism, sexism, ableism, homophobia, transphobia, and classism can result in individual and structural inequities in society. Each initiative is designed to address symptoms of oppression and prioritizes empowerment, identity development, and responsibility through facilitators, curriculum and content design and delivery. Anti-Racism Education seeks to challenge racism, inequities, prejudices, and discrimination based on race. It recognizes that race is a social construct rooted in Canada's history of colonialism resulting in systemic racism within our schools. The k2i academy works to create anti-racist spaces, free of racial injustice.

The final aspect of the k2i academy Inclusive Design Framework involves implementation at an individual, instructional and institutional level. Each individual who is a part of this work must be willing to identify and confront their biases and be open to learning in order to be culturally responsive. This ensures that each individual is self-aware and is upholding the central missions of the work. From an instructional level it is critical that education practices within programs and sessions address student needs, incorporate intrapersonal experiences and create new ways of instruction that do not perpetuate inequality. On an institutional level, leaders need to critically examine processes and systems to identify areas of inequity and work towards designing new inclusive systems.

The k2i academy ecosystem currently uses the k2i academy Inclusive Design Framework as a model for how we think about organizational structures and program design. This is not a fixed framework as true inclusive design requires adaptation and flexibility when new knowledge and understanding is presented. As the k2i academy grows and evolves, so too will this framework.

2.2. Operational Framework

Integrated into the k2i academy Inclusive Design Framework (Figure 1) is the operational framework. This framework (Figure 2) identifies three key levels: organizational level, program level and session level.

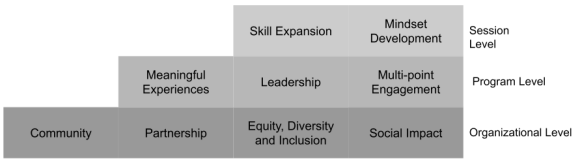

Figure 2: k2i academy Operational Framework

The organizational level (Table 1) identifies the central missions that are foundational to the work at k2i academy. k2i academy designs with community through strong partnerships. It works with equity, diversity and inclusion at the forefront of all thinking with a goal to make social impact by creating more equitable and inclusive experiences for students.

Table 1: Organizational Level

Community	Bringing together willing partners and co-learners within the ecosystem to identify persistent challenges within STEM education and work in collaboration to design, implement, test, and iterate on co-designed initiatives.
Partnership	Redefining partnerships to be reciprocal relationships, bringing together expertise, resources, skills, knowledge, and experiences unique to the ecosystem for system change.
Equity, Diversity, and Inclusion	Creating a multi-sectored ecosystem with diverse thought leaders, perspectives, and opportunities for collaboration to develop initiatives that are culturally relevant and responsive to learners.
Social Impact	Addressing the system level challenges within education and building an infrastructure that provides underrepresented youth with STEM learning opportunities.

The program level (Table 2) focuses on creating meaningful experiences for diverse learners, building leadership, and ensuring sustained engagements with a commitment for relationship building through multi-point engagements.

Table 2: Program Level

Meaningful Engagements	Creating culturally relevant and responsive programs, increasing scientific and agential literacy in STEM and students' sense of responsibility for social and environmental justice.
Leadership	Leadership development of multi-sector partners, co-learning to design and implement STEM programs that disrupts STEM education.
Multi-point Engagement	Creating sustained, long-term relationships that support positive STEM identity development and skill acquisition through mentorship.

The session level (Table 3) seeks to design programs that support youth on their journey to self discovery - providing early exposure to STEM learning and equipping all students with an opportunity to make informed decisions about their futures.

Table 3: Session Level

Skill Expansion	Strengthening competencies in coding and computational thinking, scientific understanding, application of mathematics and engineering design with a focus on hands-on learning experiences connected to solving real-world problems inspired by the UN Sustainable Development Goals.
Mindset Development	Creating a space for students to engage in learning and problem solving through their interests, lived experiences and perspectives. Encouraging students to pursue interests in social justice. Developing skills in communication, critical thinking, creative problem solving, and adaptability.

3. Application of the Framework

The k2i academy Inclusive Design Framework is implemented across our four program streams. The program streams are Bringing STEM to Life: In Schools, Bringing STEM to Life: Community, Bringing STEM to Life: Work-Integrated Learning and STEM Education Leadership Development. To maximize engagement, different programs align to different points in an educational journey (Figure 3). In addition, mentorship from individuals in post-secondary and industry not only supports the streams of programming but provides professional development opportunities.

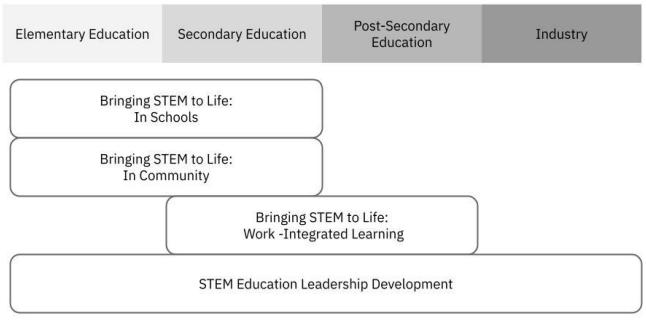

Figure 3: Educational Journey Engagement

3.1. Bringing STEM to Life: Work-Integrated Learning

To illustrate how the k2i academy Inclusive Design Framework is applied to program design and implementation, this section focuses on the Bringing STEM to Life: Work-Integrated Learning program as an example.

Work-Integrated Learning takes place over the summer months providing high school students with a paid work experience combined with a high school credit. With the student at the centre of design, the intrapersonal and interpersonal factors in the framework are considered. This program considers the barriers that youth and families may face and works with sector partners to better understand the unique experiences and circumstances that might impact interest, opportunities and engagement in STEM learning. Table 4 outlines the factors considered in the design of the program within the framework.

Table 4: Starting with the Student

Framework	Program Design Considerations
Student	Underrepresented students in STEM including Black youth, Indigenous youth, and girls.
Intrapersonal	Financial commitments requiring summer work limiting access to enrichment programs. Application process that includes previous experiences and academic performance. May have limited access to networks and mentors in STEM. Students may have been told they are not good at math and science. May not live close to a post-secondary institution.
Interpersonal	Many students are not enrolled in physics and/or additional STEM courses beyond Grade 10. Streaming into Academic and Applied courses have limited access to STEM pathways for diverse students. Collaboration with K-12 school boards and community partners required.

The k2i academy worked with advisors, providing diverse perspectives. Through this collaborative work, k2i uses the operational framework to create and implement the programs. (Table 5)

Table 5: Bringing STEM to Life: Work-Integrated Learning programs - Operational Framework

Framework	Program Design
Operational Level	Bringing together post-secondary, school boards, community organizations, and advisors from Indigenous and Black communities to create programming. Program inspired by the UN Sustainable Development Goals. Create an inclusive learning space that is culturally relevant and responsive to learners. Provide Equity, Diversity, and Inclusion (EDI) professional learning.
Program Level	Provide diverse learning experiences between physics learning, project-based learning, and mentoring. Provide mentorship to students. Mentors developed leadership skills. Meaningful experiences for all participants including undergraduate mentors, physics teachers, school board leaders, research faculty advisors, and community groups.
Session Level	Mindset for personal goal setting and success through mentorship and wraparound support provided in the program. Students develop skills including engineering design, scientific research, computational thinking and coding, collaboration, communication and creative problem-solving. Connected to UN Sustainable Development goals and social justice. Undergraduate mentors gain transferable skills, self-actualization and a deeper understanding of STEM.

The final foundational components of the k2i academy Inclusive Design Framework provides the overall theoretical framework to guide decision making and reminds us of our responsibilities to ensure that this work creates impact. By recognizing that successful implementation happens at the individual, instructional, and institutional level, it guides us to think about how we design programs to dismantle institutional barriers,

instructional barriers, and the individual barriers that are preventing change. In this program, the multi-sector partners needed to design new processes to: hire high school students, to enrol students in summer physics classes, recruit and hire physics teachers willing to work in adaptive ways with collaborators across institutions, co-create real-world projects connected to the UN Sustainable Development Goals and student interests with research faculty and undergraduate mentors and seek funders to enable the full delivery of the program. This work was guided by theoretical frameworks in critical theory, anti-oppression theory, and anti-racism education which reminds us to think critically about our system, work alongside partners and students to design programs that are adaptive to learner needs and interests, and work to dismantle racism and oppressive structures to provide more equitable outcomes for students.

3.2. Program Outcomes

The application of the k2i academy Inclusive Design Framework created a program that reached 90 high school students across 3 Greater Toronto Area (GTA) school boards for 140 hours of paid virtual work and learning. A team of 4 high school physics teachers delivered both the Grade 11 University and Grade 12 College Physics courses to address streaming (academic and applied in grade 10) and 24 undergraduate mentors led the project-based learning experience with 9 research faculty advisors. The program consisted of 86% girls, 28% Black youth, and 4% Indigenous youth. 86% of participants shared that the program improved their ability to make mistakes and persevere through problems and 71% stated the program improved their confidence in addition to technical skill development. 99% of students in the program received their high school physics credit. When students were asked what their most powerful learning moments were, they shared:

> "Seeing that there were other girls who look like me who are as interested in STEM as I am" - Grade 10 Student

> "The most powerful learning moment I experienced during this program was learning how diverse STEM really is. I am much more interested in pursuing a STEM career due to the wide range of options to choose from." - Grade 10 Student

> "That we can solve anything if we put our mind to it and follow a structured thinking process (engineering design process) rather than just dive into problems and feel overwhelmed. I feel that I can do anything!" - Grade 11 Student

4. Conclusions

The k2i academy Inclusive Design Framework provides a process that enables organizations and institutions to design and implement intentional, equity-focused programs. The framework was used to design and implement the Work-Integrated Learning program presented in this paper, demonstrating the potential for high impact programming that reaches students who are unlikely to consider STEM pathways. Creating equity-focused programs must start with the student and understanding that it is our responsibility to better understand the needs and interests of the students and families we serve. The framework requires us to partner strategically and in innovative ways to strengthen our efforts and leverage our collective experiences, resources, and knowledge to tackle symptoms of oppressive structures in our educational system. By working strategically with GTA school boards to identify students who would otherwise not consider programs like this, and considering potential barriers to opportunities for students and families, the framework enabled the design and implementation of a high impact, equity-focused program that was multifaceted in its approach.

Designing and implementing programs to reach youth without this framework does create results, however, these results may not be equity-focused. For example, if we did not work with the school board and instead used an application process, we will reach students but we may not reach the same students that this program was designed for. Additionally, we would be challenged to provide a high school credit as part of the experience without this strategic partnership as k2i academy is not a private school. Working with partners to better understand the STEM education ecosystem and putting students at the center of the work to ensure that the experience is culturally relevant and responsive to learners is a critical component of the framework. The framework provides a critical lens to the work by considering the individual, instructional and institutional responsibilities of all collaborators. Without considering these components, we will continue to struggle to create equity-focused programs.

k2i academy is forever learning from our programs and as we learn alongside our partners within our ecosystem, we are evolving, adapting and iterating. We are committed to creating a dynamic ecosystem for social innovation and disruptive change in STEM education.

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