UNDERGRADUATE MENTORS' PERSPECTIVES ON EQUITY-ORIENTED STEM OUTREACH

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Abstract – *This paper explores undergraduate mentors' perspectives on, and participation in, "Bringing STEM to Life: Work Integrated Learning in Physics" (BSTL), a work-integrated, equity-oriented STEM outreach program administered by the kindergarten to industry (k2i) academy at York University's Lassonde School of Engineering. To that end, this study brings Feminist Science and Technology Studies and critical pedagogy to bear on a three-phase methodological approach to generating and analyzing qualitative data pertaining to the mentorship component of BSTL. Preliminary findings suggest that (1) undergraduate mentors bring complex STEM motivations, shaped by intersecting marginalized identities, to bear on their mentorship duties; (2) mentors possess nuanced yet occasionally contradictory understandings of STEM, equity, and society; and (3) mentors' experiences in the BSTL program are variable but positive. These findings suggest that outreach programs can expand their capacity to generate equitable outcomes by actively supporting the creation of STEM counterspaces, foregrounding equity training, and exposing mentors to critical theoretical perspectives on STEM, equity, and society.*

Keywords: Mentorship; Equity, Diversity and Inclusion; STEM Outreach

1. INTRODUCTION

1.1 Research Problem

Mentorship programs are considered a pivotal component of equity-oriented initiatives in formal and informal, STEM- and engineering-education contexts. For students in STEM (i.e., science, technology, engineering, and mathematics) who are gendered, racialized, or otherwise minoritized, mentorship programs are associated with a variety of beneficial outcomes [1]-[2]. Though studies of mentorship programs often focus on measuring outcomes, it is also important to consider the relational complexities associated with the mentorship process [3]. These complexities are especially important in the context of STEM outreach programs which include a mentorship component, as even the most well-intentioned programs are liable to reinforce existing inequities [4]. For this reason, mentors must be adequately prepared to attend to the particular needs of their mentees. Mentees' needs vary, however, not just because each student is unique, but also because of the variability generated by differences in local and institutional contexts [5]. Consequently, it can prove problematic to apply generalized, top-down 'best practices' to particular mentorship processes.

Best practices for mentorship in STEM must emerge, this paper contends, from the bottom-up – that is, by engaging critically with mentors' and mentees' perspectives on mentorship in particular STEM- or engineering-education contexts. This paper, which summarizes the preliminary findings of a more comprehensive study, is concerned with the mentor side of the mentor-mentee relationship. To that end, this paper explores undergraduate mentors' perspectives on, and participation in, "Bringing STEM to Life: Work Integrated Learning in Physics" (BSTL)—a work-integrated, equity-oriented STEM outreach program administered by the kindergarten to industry (k2i) academy at York University's Lassonde School of Engineering—by way of three research questions:

1) What are mentors' perspectives on equity in STEM?
2) What are mentors' experiences in BSTL?
3) Do these findings reveal opportunities to improve BSTL's capacity to generate equitable outcomes, or offer insights concerning equity-oriented STEM outreach more broadly?

1.2 Outreach Context

At York University's Lassonde School of Engineering (LSE), only 0.8% of undergraduate students identify as Indigenous and 15.6% identify as female. These figures have stagnated since 2014, when 1.3% of LSE undergraduates identified as Indigenous and 16% identified as female [6]-[7]. It was in this context that, in March 2020, LSE created the k2i academy, a STEM outreach hub established with the explicit intent to dismantle systemic barriers to, and diversify representation in, STEM education and professions. To that end, k2i academy collaborates with school boards, government ministries, researchers, educators, community organizations, and a variety of additional external partners to conceptualize, design, and administer a variety of STEM outreach programs, including BSTL.

BSTL is a work-integrated, equity-oriented summer physics program geared towards high school students who are racialized, gendered, or otherwise minoritized. To identify equity-deserving students, k2i academy collaborated with three Toronto-area secondary school boards to identify schools situated in neighbourhoods that are facing considerable socioeconomic challenges. The BSTL program was advertised to students within these schools not just as an opportunity to earn a physics credit (i.e., SPH3U or SPH4C), but also as a unique part-time summer job. Ultimately, k2i academy hired a total of 90 students from 31 Toronto-area schools to participate in the 2021 iteration of the program as 'lab assistants.' Over the course of the five-week program, which was delivered virtually in 2021, students engaged in synchronous and asynchronous program-related activities for approximately 175 hours (140 of which were paid). In addition, to facilitate program-related activities, k2i academy hired four Toronto-area high school teachers to lead synchronous physics lessons aligned with the Ontario science curriculum, as well as 24 undergraduate students to support teachers and serve as mentors for the high school students.

During the first week of the program, students spent the majority of their time attending synchronous, teacher-led physics lessons and engaging in hands-on activities. (Students were also provided with asynchronous work periods to complete assigned work, and mentors provided them with tutoring and support throughout the program.) In weeks two through five, physics lessons were reduced to two hours per day, freeing up several hours each day for students to work in project teams. These project teams—each of which consisted of two mentors and up to 10 students—met daily with a faculty advisor, who guided them through the process of designing and executing research projects aligned with the United Nations Sustainable Development Goals (SDGs). On the last day of the program, k2i academy hosted a virtual research showcase on Gather Town, where project teams presented posters detailing their respective research projects.

In addition to facilitating the activities described above, undergraduate mentors spent a minimum of 12 days training for their roles. Mentor training sessions spanned a variety of important topics, including computational thinking and coding; project planning and leadership; connecting STEM activities with the Ontario science curriculum; and collaborating with faculty advisors. Moreover, in keeping with its commitment to confronting systemic discrimination in STEM education, k2i academy provided all mentors with anti-racism and anti-oppression equity training. This paper—which forms a small part of a broader, more comprehensive study of BSTL—is principally concerned with undergraduate mentors' perspectives on, and experiences in, this program.

1.3 Research Context and Significance

Students who are racialized, gendered, or otherwise minoritized continue to be underrepresented in science and engineering programs at postsecondary institutions in Canada. Today, this problem is the subject of a variety of institutional interventions, including not just mentorship programs (e.g., [8]), but also outreach programs (e.g., [9]), access programs (e.g., [10]-[11]), and bridging programs (e.g., [12]). These programs are designed to improve marginalized students' access to, and persistence in, undergraduate science and engineering programs. And yet, inequities persist in postsecondary STEM- and engineering-education contexts [13]-[14].

This study is motivated not just by an appetite for social justice, but also by a desire to ensure that the STEM professions of tomorrow are prepared to confront complex, twenty-first century challenges like anthropogenic climate change. STEM professions have long been entangled with, and shaped by, racial capitalism and settler colonialism [15]. The extent of this entanglement is reflected in the culture of STEM, which privileges whiteness [16] and masculinity [17], as well as extractivist modes of inquiry characterized by hierarchical, dualistic thinking [18], anthropocentrism [19], depoliticization [20], and hyper-individualism [21]. These predilections shape the conditions of possibility which determine how STEM professionals conceive of complex sociotechnical problems. Therefore, to address the persistence of inequities in, and reform the hegemonic culture of, STEM education is also to reimagine how STEM professionals solve problems and relate to the world [22]. This means that, in the context of climate change, the persistence of inequities in STEM is not just a social justice problem, it is also an existential one.

1.4 Literature Review

Historically, the underrepresentation of gendered, racialized, and minoritized students in STEM education has been conceptualized in terms of a 'leaky pipeline' (e.g., [23]). This metaphor, which was initially used to draw attention to the underrepresentation of women in particular, suggests that students from particular backgrounds are prone to 'leaking out' of the STEM pipeline. That is, in K-12 or postsecondary educational contexts, students who are gendered, racialized, or otherwise minoritized opt out of important science, mathematics, or engineering classes—i.e., those which function as prerequisites to STEM degrees and careers—at a much higher rate than their White, cis-male counterparts [21]. It would be more accurate, however, to describe marginalized students as being actively *filtered* out of the pipeline, not as passively *leaking* out [24]-[25]. The problems with the pipeline metaphor do not end there. In addition to limiting the articulation of alternative approaches to STEM education [25]-[26], the pipeline metaphor lends itself to deficit-based STEM education research.

Deficit-based STEM education research is predicated on the assumption that marginalized students are underrepresented in STEM because they are lacking something [27]-[28]. On this view, marginalized students are lacking the requisite motivation to pursue a career in STEM (e.g., [29]); they do not know how interesting STEM is (e.g., [30]); or they have ‘misperceptions’ about STEM professions (e.g., [31]). Owing to the prevalence of these approaches, the validity of which is often taken for granted [32], marginalized students’ perspectives on STEM education are historically understudied. As Feminist Science and Technology Studies (Feminist STS) scholars have long argued, however, those marginalized by STEM possess a privileged vantage point from which to critique STEM fields [33]-[34]. Today, researchers are increasingly foregrounding marginalized students’ perspectives (e.g., [4], [35]-[36]), but these perspectives have received limited attention in Canadian educational contexts.

Whereas deficit-based STEM education studies are principally concerned with what marginalized students are lacking, asset-based studies (e.g., [37]-[38]) focus on what students have. Asset-based studies strive to generate resources that marginalized students can use to bolster their chances of persisting and thriving in STEM education contexts. These approaches can also prove problematic, however, as they teach marginalized students to code-switch (i.e., conform to dominant modes of existence in the classroom), but they do not necessarily challenge the cultural hegemonies which make code-switching necessary in the first place [39]. Consequently, asset-based studies may individualize systemic problems, leaving the status quo intact in the process.

In light of the problems associated with the prevailing approaches to STEM education research, this paper endeavours not just to contribute to extant scholarship of mentorship in outreach contexts (e.g., [2]-[3], [5], [40]), but also to answer Shakhnoza Kayumova and colleagues’ call [22], [41] for a shift from empowerment to response-ability in STEM education.

1.5 Theoretical Framework

This study brings Freirian critical consciousness [28], [42] to bear on the proposed shift from empowerment to response-ability in STEM education. This understanding of critical consciousness (or concientização) is rooted in the liberatory pedagogy of Paulo Freire. Through dialogue, Freire’s pedagogy “makes oppression and its causes objects of reflection by the oppressed”, thereby engaging them as active participants in “the struggle for their liberation” [42, p. 48]. In the context of this study, marginalized students can be said to have achieved critical consciousness when they recognize the status quo in STEM education “not as a closed world from which there is no exit, but as a limiting situation which they can transform” [42, p. 49].

Kayumova and colleagues’ call [22], [41] for a shift from empowerment to response-ability in STEM education is rooted in Feminist STS in general (e.g., [33]-[34]), and Karen Barad’s theory of agential realism [43] in particular. Agential realism brings physicist Niels Bohr’s interpretation of quantum physics to bear on social theorist Michel Foucault’s understanding of power, knowledge, materiality, and discourse. By reading Bohr through Foucault, and vice versa, agential realism brings into sharp relief the inseparability of objects and agencies of observation. This move sets agential realism apart from early theories of technoscience (e.g., [44]-[46]), according to which technoscientific knowledges and artifacts are produced through *inter*actional effects. Under agential realism, by contrast, phenomena are generated not through *inter*-actions (i.e., the actions of clearly distinguishable entities), but *intra*-actions (i.e., the actions of entangled agencies). In other words, agential realism situates scientists and engineers *in* the world, obliges them to consider the ethical implications of this embeddedness, and challenges them to generate knowledges *with*, rather than conducting research *on* or extracting data *from*, others.

Along similar lines, this study takes as its starting point the position that STEM education and outreach should be concerned not with *scientific* literacy, but *agential* literacy [47]. The notion of scientific literacy goes hand-in-hand with deficit-based approaches to STEM education and outreach. That is, deficit-based outreach programs seek to address marginalized students’ supposed scientific literacy deficits, thereby ‘empowering’ and ‘inspiring’ them to pursue degrees and careers in STEM [48]. This approach situates STEM professions and professionals *apart from* societies and cultures. Consequently, deficit-oriented educators are obliged to “make the subject matter relevant by […] coating scientific facts with ‘relevant examples’ to make them go down easier” [47, p. 238]. Under agential literacy, however, digestive aids are not required because students are challenged not merely to think about STEM in its social or cultural contexts, but rather to make sense of how STEM intra-acts within the world. In other words, the shift from empowerment to response-ability is not just about acknowledging that STEM exists within the world, it is about bolstering our collective *ability* to *respond* (i.e., our response-ability) to that acknowledgement.

In line with the above, *response-able* STEM outreach programs are more likely to generate equitable outcomes than are conventional, deficit-based outreach programs. Under the latter, equitable outcomes are reduced to quantitative data (often generated via standardized, Likert scale surveys) purporting to demonstrate participants’ increased interest in STEM careers (e.g., [30]). In a response-able STEM outreach program, the bar is much higher for equitable outcomes. At minimum, on this view, an equitable outcome can be said to have been achieved if, by virtue of their participation in the program, marginalized students generated resources to bolster their chances of persisting and thriving in STEM education contexts (as in the asset-based approaches described above). A more equitable outcome is achieved when participants come to a deeper understanding of how STEM intra-acts within the world [47]. A *still* more equitable outcome is achieved when participants develop a critical consciousness with respect to the persistence of inequities in STEM education. Finally, a maximally equitable outcome is achieved when marginalized students take it upon themselves to actively disrupt, resist, or subvert the hegemonic culture which prevails in STEM education contexts [22].

In keeping with our commitment to conducting research as praxis, it is important to establish our respective standpoints. Callum Sutherland is a White, cis-gender man. Aida Mohammadi is an Iranian-Persian cis-gender woman. Jeffrey Harris is a mixed-race (White and Chinese) cis-gender man. In addition, all three authors are settlers. It is doubtless that our situatedness coloured our approach to writing this paper and carrying out the underlying study. This underscores the importance, we suggest, of designing a methodology which foregrounds marginalized students' perspectives on equity-oriented STEM outreach.

2 METHODOLOGY

To foreground marginalized students' perspectives on STEM, this empirical study brings a modified version of the Delphi method to bear on a three-phase methodological approach to generating and analyzing qualitative data.

2.1 The Delphi Method

In a conventional Delphi study (e.g., [53]), a panel of experts (i.e., the research participants) is convened to produce a consensus with respect to a topic within their area of expertise. To that end, the panellists participate in two or more rounds of data generation, beginning in round one with an open-ended questionnaire. In successive rounds, the questionnaire becomes more restrictive as researchers attempt to incorporate panellists' previous responses. This cycle continues until the panellists are deemed to have reached a consensus. Conventionally, this consensus (along with the data thus generated) is expressed in quantitative terms.

This study differs from conventional Delphi studies in several respects. First, this study builds on existing adaptations of the Delphi method (e.g., [49]-[52]) to generate qualitative data. Second, whereas Delphi studies often take for granted, and are therefore liable to reproduce, traditional understandings of expertise, the Delphi method is used in this study to foreground perspectives that are undervalued by conventional taxonomies of expertise. Third, this study uses the Delphi method not to shepherd participants towards a consensus, but to allow them to shape the direction of the study and (in)validate the research team's interpretation of the data thus generated.

2.2 Sampling and Research Participants

Undergraduate students were recruited to participate in this study via email. To that end, the research team provided k2i academy staff with an email script, which they forwarded to the undergraduate students who served as mentors in the BSTL program. This script introduced the research team, described the study, and directed interested individuals to an online survey which facilitated the informed consent process. No inducements were offered or provided. Ultimately, seven undergraduate mentors volunteered to participate in this study. It is worth reiterating that this paper is reporting on the preliminary findings associated with just one (i.e., undergraduate mentors) of two participant groups, and three (i.e., the first to complete the final round of data generation) of the seven participants within this group. In other words, this is a 'small n' study [54] that is concerned not with generating statistically-representative quantitative data, but rich and textured qualitative data (see Section 4.2 for a discussion concerning the limitations associated with this approach).

2.3 Phase 1: Demographics and Perspectives

In the first phase of this study, the research team administered an online questionnaire to generate a demographic profile of the research participants and to explore their perspectives on a variety of general topics.

This questionnaire asked participants to identify with particular racial, cultural, religious, and gender identities, sexual orientations, (dis)abilities, socioeconomic statuses, and household situations. Survey items concerning Indigenous identities were adapted from Statistics Canada's 2021 census categories, which were developed following a national consultation process [55]. These survey items were then reviewed by York University's Centre for Indigenous Student Services, whose feedback was subsequently incorporated into the survey. In addition, survey items concerning disabilities were adapted from Statistics Canada's Canadian 2017 Survey on Disability [56]. Additional demographic survey items were adapted from those used in the Toronto District School Board's parent and student census [57].

In addition, participants were also asked to identify their field of study, describe their STEM (or non-STEM) career plans, and speak to their perspectives on a variety of broad topics relating to STEM, equity, and society. Survey items were associated with a variety of question types, including multiple-choice, short-, and long-answer questions, ranked lists, and an opinion matrix. Branching logic was used to tailor survey items to each participant. Opinion matrix questions were associated with only three responses: (i) this is not my opinion; (ii) this is kind of my opinion; and (iii) this is totally my opinion. To enhance data validity, each opinion-matrix survey item was paired with an opposing item (e.g., “STEM professionals need both social and technical skills.” vs. “Social skills are not important for STEM professionals.”). In addition to enhancing the validity of opinion-matrix survey items, this approach helped the researchers identify contentious topics (e.g., the place of the UN SDGs in the BSTL program).

The data thus generated were subjected to multiple rounds of qualitative analysis by at least two members of the research team. Throughout this process, the researchers wrote analytic memos [58] which they discussed at regular meetings. During the first round of analysis, the researchers reviewed and reflected on participants’ responses without segmenting or coding the underlying text. In round two, the researchers used open coding to identify themes emerging from the data [58]. In subsequent rounds, the researchers used the constant comparison method [59] to scrutinize, (in)validate, and consolidate codes. This process continued until the researchers no longer observed the need to create new codes or revise existing codes. The themes thus identified were then used to design the questionnaires administered in phase two.

2.4 Phase 2: Experiences in BSTL and STEM

In phase two, the research team administered a second questionnaire to build on the data generated during phase one, as well as to explore participants’ experiences in the BSTL program and in STEM education more generally. These questionnaires were designed to further explore the recurring themes and contentious topics which emerged during phase one. In line with the previous questionnaire, survey items were associated with a variety of question types, and branching logic was used to tailor survey items to individual participants. Participants who indicated that they have experienced or witnessed discrimination in STEM education, for instance, were asked to describe their experiences. Participants were also asked open-ended questions concerning how best to combat discrimination in STEM education. Opinion matrix questions probed participants’ experiences in the BSTL program. As in the previous phase, each opinion-matrix survey item was paired with an opposing survey item to enhance data validity and identify contentious topics. The data thus generated were then subjected to multiple rounds of qualitative analysis by at least two members of the research team using the same approach employed during phase one. This analysis attuned the researchers to the existence of a number of recurring themes and contentious topics, which informed their approach to designing questionnaires for the interviews conducted in phase three.

2.5 Phase 3: Validation and Provocation

In phase three, the lead author conducted open-ended, online interviews with each research participant. These interviews were designed not just to build on, flesh out, and validate the data generated in phase one and two, but also to develop participants’ critical consciousness [28], [42]. To that end, the researchers prepared for interviews by creating tailored questionnaires for each participant informed by their respective (i) STEM motivations and ambitions; (ii) opinion-matrix responses, with an emphasis on those requiring validation; and (iii) any recurring themes or contentious topics which emerged during their participation in phases one and two. In addition, the lead author prepared a series of images to illustrate critical theoretical perspectives on STEM, equity, and society.

At the start of each interview, participants were given the opportunity to choose their own pseudonym. To facilitate the de-identification of interview data, participants were asked to replace their display name with their chosen pseudonym. Interviews, which ranged in length from 60 to 90 minutes, were conducted online via Zoom. The lead author used screen-sharing to allow participants to see the interview questionnaire, and to display images illustrating critical theoretical perspectives. Each interview was recorded to automatically generate an interview transcript. These AI-generated transcripts were edited extensively to correct transcription errors. To enhance the clarity and readability of interview transcripts, most ‘filler words’ (e.g., “um” and “you know”) were deleted during the transcription process. Otherwise, the interviews were transcribed verbatim.

Interview transcripts were subjected to multiple rounds of qualitative analysis by at least two members of the research team, using the same approach employed during phases one and two. In what follows, this paper summarizes the preliminary results of this analysis.

3 PRELIMINARY FINDINGS

Preliminary findings suggest that (1) undergraduate mentors bring complex STEM motivations, shaped by intersecting marginalized identities, to bear on their mentorship duties; (2) mentors possess nuanced yet occasionally contradictory understandings of STEM, equity, and society; and (3) mentors’ experiences in the BSTL program are variable but positive.

3.1 Complex STEM Motivations

The undergraduate mentors who participated in this study—each of whom identify with intersecting marginalized identities—have complex STEM motivations. The complexity of these motivations is illustrative of the importance of attending to the complex processes through which STEM motivations are often informed by the experience of intersectionality.

‘Mandarin’ (pseudonym) is a mechanical engineering student and first-generation Canadian who identifies as a Middle Eastern, Muslim cis-gender man. Mandarin developed an interest in mechanical engineering at a young age, and he credits his father for nurturing that interest. Today, Mandarin is motivated to pursue a career in mechanical engineering principally by his desire to make his parents happy, and to take care of them financially. Though Mandarin is also driven by a desire to be a productive member of his religious community, he does not intend to bring his mechanical engineering expertise *directly* to bear on issues facing this community. Interestingly, despite identifying with multiple marginalized identities, Mandarin ranked "I want to feel like I belong" as his least-important STEM motivation.

'Leena' (pseudonym) is a space engineering student and first-generation Canadian who identifies as a Middle Eastern, Muslim cis-gender woman. Leena felt drawn to space engineering not just because she has always been interested in math and physics, but also because it forces her outside of her comfort zone and it speaks to her curious mind. In pursuing a career in space engineering, Leena is motivated by her intellectual curiosity, and by her desire to create things. Leena's lowest-ranked STEM motivations, on the other hand, were "I want to help my community" and "I want to help my family."

'Cassandra' (pseudonym) is a computer science student and first-generation Canadian who identifies as a Black, Christian cis-gender woman. One year, as a high school student, Cassandra spent her summer break designing a website. In the process, she learned HTML and CSS, and developed an interest in computer science. Today, Cassandra is nearing the completion of her computer science degree. She is uninterested, however, in following what she calls the "typical career path" for computer science graduates – that is, pursuing a job at a large tech company like Google. Instead, Cassandra is planning to engage with small-scale technologies in various African communities with a view towards "figuring out what drives people to create things to help themselves and their communities", as well as to dispel "misconceptions about African countries." For Cassandra, in other words, corporate STEM careers are in direct conflict with her principal STEM motivations. In deficit-based studies concerning the communal affordance hypothesis (e.g., [60]), Cassandra's perspective on corporate STEM careers would be considered erroneous. On this view, Cassandra's position is based on a 'misconception' – namely, "that science does not involve communal goals" [60, p. 641]. It is apparent, however, that Cassandra's position is based not on a misconception, but on a nuanced understanding of how STEM intra-acts within the world. This is also true of Mandarin and Leena, as detailed below.

3.2 Nuanced, Ambivalent Perspectives on STEM

Mandarin, in particular, has a sophisticated understanding of how STEM intra-acts within society. When asked, for instance, to speak to the persistence of discrimination in STEM, Mandarin argued that "STEM doesn't exist in isolation – it is embedded in the reality of its society, and […] it is inevitable that certain cultural norms will seep into STEM." On how best to address discrimination in STEM, then, Mandarin argued that

> there's no point in sugar-coating it, but [we] shouldn't paint it as a hopeless cause either. There is room in the middle of those two extremes where real civil action can be taken to make sure that the values of the hegemonic majority are not imposed on the minority.

When asked to elaborate on this point, Mandarin offered a detailed explanation of how systemic White privilege perpetuates itself. Mandarin also exhibited considerable self-awareness with respect to his relative privilege as a man. In STEM education contexts, Mandarin argued, Muslim men have an easier time fitting in than do Muslim women, as the latter may be more visible by virtue of their hijabs. Along similar lines, Mandarin noted that women in STEM are, unlike men, routinely judged for their physical appearance. Interestingly, however, Mandarin described the 'natural' differences between men and women in a manner that is consistent with the complementarity hypothesis [61]. Consequently, even though Mandarin expressed his commitment to "including female students as much as possible", this raises the spectre of unconscious bias [62] adversely impacting upon his relations with female mentees. Mandarin acknowledged, however, that "this bias can show" and that "sometimes it can be unconscious."

Leena, likewise, brought to her role a nuanced yet ambivalent understanding of how STEM intra-acts within society. When asked to speak to the persistence of discrimination in STEM, for instance, Leena pointed to the distinction between "female majors" and "male majors", and argued that this distinction is based on perceived differences between men and women that "are rarely based on facts." Interestingly, despite having clearly identified an instance in which STEM and politics are entangled, Leena spoke elsewhere of STEM and politics as separate domains. Leena also offered an explanation for the gender imbalance in engineering, which she attributed not just to White, cis-male privilege, but also to the institutional perpetuation of that privilege. Though Leena acknowledged that more needs to be done to address the resulting inequities, she suggested that the solution to this problem was to increase the scale of outreach initiatives like BSTL. Early in her undergraduate studies, however, Leena was subjected to discrimination at the hands of her classmates, an experience which may have led to her subsequent struggles with imposter syndrome. Despite this experience, Leena's proposed solution did not account for the toxic elements of STEM culture. When the need for a more comprehensive solution (e.g., one that also involves ongoing peer mentorship) was put to her, however, Leena responded candidly and enthusiastically:

> I've always thought about getting students [from marginalized backgrounds] to university, but I never really thought about what happens once they're in university. I think that's an important point to explore.

"That continuous support is really important", Leena added, "especially for a student navigating university straight out of high school."

In addition to demonstrating her understanding of how STEM intra-acts within society, Cassandra was critical of STEM education for lacking in response-ability. In speaking to why she decided not to pursue a career in computer science, Cassandra explained:

> In STEM, we don't necessarily talk about [society]. We do talk about it [in] liberal arts courses, [where we can explore] the cultural reflection of things, and where there is a little more understanding in terms of how humans interact with other humans. STEM focuses more on doing things everywhere, and creating solutions, but not about the impact of those solutions.

Cassandra was critical of corporate STEM careers for the same reason – that is, for corporations' failure to adequately account for their situatedness within the world.

> I've noticed during my job search that employers want you to fit [their] culture, and it makes me feel conflicted. For example, [I don't agree with] Facebook, and [the way its] Instagram platform affects younger teenagers, but if you decide to work at Facebook, you are obligated to […] do the tasks that you're asked to do […]. Ideally, as a STEM professional, you should always be considering [the] impact [of your work] – but, realistically, that's not always possible.

Interestingly, though Cassandra went on to acknowledge that digital creations always reflect their creators' values and perspectives, she also spoke of programming languages in instrumentalist terms [63]. Cassandra also expressed some discomfort concerning equity-oriented STEM outreach initiatives designed specifically for Black students. Outreach programs, Cassandra argued, should cater to students experiencing poverty, regardless of race. For Cassandra, in other words, these outreach programs run the risk of conflating Blackness with powerlessness.

3.3 Variable Experiences in BSTL

In light of their diverse identities, experiences, and perspectives, mentors' experiences in the program varied in several respects. Cassandra felt, for instance, that the program was focused too narrowly on physics and engineering. As a computer science student, Cassandra would have liked to have seen a greater focus on other STEM disciplines. Mandarin and Leena, on the other hand, are engineering students interested in physics. As such, they were content with the program's focus.

This experiential variability was particularly evident in participants' experiences leading the design of UN SDG-aligned research projects. These projects, it should be noted, were designed in consultation with (volunteer) faculty research advisors, whose level of enthusiasm and perspectives (e.g., on STEM and the UN SDGs) would surely have varied. Leena spoke very highly of her faculty research advisor, whom she credited for guiding her project team through the process of choosing an SDG around which to design their project. Leena argued that the SDGs helped her students think about how STEM relates to specific issues. Mandarin was less enthusiastic, but he found the SDGs useful for the same reason. Interestingly, whereas Leena's team designed their research project with their chosen SDG in mind, Mandarin's team applied an SDG to their research project after the fact. For Mandarin's team, in other words, engagement with the SDGs was "very surface level." Cassandra was more critical of the SDGs. Cassandra and her team met with their faculty advisor to discuss the SDGs, but she described this discussion as a sort of "check box." It was not clear, Cassandra argued, how the SDGs related to issues of social or environmental justice.

Despite this experiential variability, participating mentors described their experiences in the BSTL program in overwhelmingly positive terms. Mandarin enjoyed cultivating a sense of community within his project team. Leena, meanwhile, realized a stronger sense of belonging in STEM through her mentorship duties:

> Through my work, I gained that sense of belonging by creating a space for younger students to also feel like they belong. Subconsciously, [this] made me feel like I belonged, because it made me feel like, well, I'm paving a path for students, and therefore I also belong here. I also have a space here.

Cassandra offered a similarly enthusiastic assessment of her experience as a mentor in the program, noting in the process that it is "mind boggling how effective this program is." In addition, all three participants praised the work-integrated learning component of the program, without which, they said, it would have been difficult to justify their involvement, particularly given the associated time commitment and the importance of earning income during the summer break.

4 DISCUSSION

In addition to generating insights concerning equity-oriented STEM outreach in general, the preliminary findings summarized in this paper reveal several opportunities to improve the BSTL program's capacity to generate equitable outcomes. These recommendations may also prove useful in a variety of outreach contexts.

4.1 Implications

First, throughout their participation in this study, Mandarin, Leena, and Cassandra repeatedly highlighted the importance of establishing and actively supporting STEM counterspaces. Counterspaces, Maria Ong and colleagues explain, are "safe social spaces […] which offer support and enhance feelings of belonging" for marginalized students in STEM [21, p. 207]. Mandarin articulated the importance of these spaces in this way:

> I think having a safe spot, where people can talk about 'all this happened to me', is really important […]. You might realize, 'oh yeah, that happened to me, too', and [if] many people start to realize that they've had the same experience, that's [when] communities […] say, 'this shouldn't happen again.' But if you're just atomized individuals, living alone, without any support systems, then it's much easier for people to pick on you, to break you apart.

Though it is doubtless that BSTL qualifies as a STEM counterspace, it is also a temporary one. As such, its capacity to generate equitable outcomes is temporally limited. For this reason, the Lassonde School of Engineering should consider establishing a longer-term, work-integrated mentorship program specifically for BSTL alums. It may also prove beneficial to organize regular 'reunion' meetings for program alums. These initiatives would allow mentors and students to capitalize on the momentum that was built up over the course of the BSTL program. For individual students, on the other hand, it may prove difficult to maintain this momentum.

Second, though Mandarin, Leena, and Cassandra each possess a nuanced understanding of STEM, equity, and society, the ambivalences which emerged over the course of their participation in this study pointed to opportunities to improve mentors' equity training. In the early stages of this study, for instance, all three participants conflated the meaning of equity (i.e., fair outcomes) and equality (i.e., equal opportunities). When this was clarified during the interviews, all three participants immediately grasped the significance of this distinction, particularly as it relates to the persistence of inequities in STEM. In light of the potential for programs like BSTL to reinforce existing inequities [4], k2i academy should consider foregrounding and expanding on its equity training. During the 12-day mentor training program, equity-centric training sessions were concentrated on days 9, 11, and 12. By foregrounding some or all of these training sessions, k2i academy can better equip undergraduate students to bring an equity lens to bear on their mentorship duties.

Third, in line with the above, it may also prove beneficial to expand the training program to 13 days to make room for a full-day Science and Technology Studies (STS) workshop designed to expose mentors to critical theoretical perspectives on STEM, equity, and society. An STS workshop would go beyond merely affirming that all genders are equal, for instance, by challenging mentors to consider the concrete sociotechnical processes through which sex and gender—and, by extension, our collective understanding of sex- and gender-based differences—have historically been constructed. By provoking mentors' critical consciousnesses, this workshop would safeguard against the reproduction of inequities via unconscious bias, in addition to expanding the program's potential to generate equitable outcomes.

4.2 Limitations and Future Research

This paper, it should be noted, is associated with several limitations. First, this paper reported on the preliminary findings associated with just three of its 15 research participants, and one half of the mentor-mentee relationship. Accordingly, certain aspects of this paper may be more difficult to understand in the absence of this broader empirical context. Second, this paper is based on a qualitative, 'small n' study which aims not for statistically-representative quantitative data, but rich and textured qualitative data capable of offering insights into the complex, lived experiences of marginalized students [54]. We are not arguing, in other words, that the research participants profiled in this paper are representative of some larger group(s). Finally, it is doubtless that the research team's positionality coloured our approach to generating and analyzing data over the course of this study. The lead author, for instance, is a White, cis-gender man and settler who conducted all the interviews carried out over the course of this study. This may have made it more difficult for some research participants to open up about their experiences as marginalized students in STEM.

In light of the above, future studies in this vein should consider using participatory methods (e.g., participatory action research). Though the Delphi method allowed us to foreground marginalized perspectives, it could be argued that this approach was inconsistent with our theoretical framework. This approach, like STEM *out*-reach more generally, maintains a distinction between inside and outside, researcher and participant. What, then, would a STEM *intra*-reach program look like? Though the answer to this question is beyond the scope of this paper, we suggest that critical, participatory research activities would be embedded in every aspect of such a program.

5 CONCLUSION

This qualitative study explored undergraduate mentors' perspectives on, and participation in, "Bringing STEM to Life: Work Integrated Learning in Physics", an equity-oriented STEM outreach program administered by the k2i academy at York University's Lassonde School of Engineering. This paper summarized the preliminary findings associated with a subset of this study's participants, contending in the process that (1) undergraduate mentors bring complex STEM motivations, shaped by intersecting marginalized identities, to bear on their mentorship duties; (2) mentors possess nuanced yet occasionally contradictory understandings of STEM, equity, and society; and (3) mentors' experiences in the BSTL program are variable but positive. These findings suggest that outreach programs can expand their capacity to generate equitable outcomes by actively supporting the creation of STEM counterspaces, foregrounding equity training, and exposing mentors to critical theoretical perspectives on STEM and society.

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