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Outreach as Research Activism: Using STEM Outreach as a bridge to Social Change

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ABSTRACT
The STEM Explorers outreach project, headed by a Faculty of Education at a University in Ontario, Canada, brings free, hands-on, and in-community science, technology, engineering, and mathematics (STEM) outreach events to children and their families from groups under-represented in STEM education and careers. The project provides pre-service teachers with experience facilitating inclusive approaches to STEM education and also creates a context to explore their conceptions of activism. The purpose of this phenomenographic research is to describe the experiences of these aspiring teachers to better understand the ways that outreach initiatives can impact their role as STEM education activists. Findings suggest that a positive STEM educator identity, a program of integrated and student-centered STEM learning, and possessing an activist sense of purpose, contribute to the degree to which pre-service teachers regard themselves as STEM education activists.

KEYWORDS
STEM outreach; STEM education activism; phenomenography; teacher education.

INTRODUCTION

The fields of science, technology, engineering, and mathematics (STEM) are pivotal in addressing global challenges. The United Nations (2022) regards STEM as a primary determinant of a country's economic development and a key contributor to peace and security (2022). In turn, STEM education is gaining increasing attention as a STEM-literate global workforce becomes an imperative. The merits of STEM education are equally tangible on the individual level. A growing body of evidence shows STEM education can improve cognitive processes including critical thinking and problem solving (Isdianti et al., 2021; Minarti et al., 2023; Savran Gencer & Doğan, 2020). Furthermore, having a STEM education can enhance future employability, socio-economic status, and political empowerment (Di Battista et al., 2023; Ghazzawi, 2021; Velasco et al., 2023).

Diversity in STEM

Canada faces a shortage of skilled STEM workers (Statistics Canada, 2021). In 2022, the federal government announced a plan to allow express entry for immigrants with qualifications and experiences in the STEM fields "Immigration, Refugees, and Citizenship Canada" (n.d.). However, employment rates in STEM fields for people who are Black, Indigenous, and from other systemically marginalized groups are disproportionately lower than for other Canadians (Statistics Canada, 2016; 2022; Conference Board of Canada, 2020). Although post-secondary STEM graduates are more likely to earn higher salaries than their peers, pay gaps are more common in the STEM fields for people from equity-deserving groups (Kazmi, 2022). In academia, Black, Indigenous and racially diverse university professors are under-represented and are more likely to experience pay inequity (Henry et al., 2016; Longfield, 2024). Despite these disparities, there is evidence of the benefits of diversity in STEM education and workplaces. A positive association has been noted between the proportion of post-secondary STEM students from under-represented racial groups and the academic achievement of *all* students in the class (Bowman et al., 2023). In the workplace context, improved creativity, problem-solving, and financial performance have been reported when teams are more diverse (Baten et al., 2021; Phillips et al. 2009; Sommers, 2006).

STEM Education

To address the aforementioned inequities in STEM and the merits of increased diversity, systemic change is necessary to improve access for children from communities that have less opportunity to engage with these fields. This research is grounded in the belief that educators have agency to create positive STEM experiences for children from equity deserving groups. Archer et al., (2010) propose that improved teaching strategies in informal learning contexts will help inspire interest in STEM by connecting learning to everyday applications (2010).

According to Mahboubi (2022), impactful pre-service experiences for teachers can ensure learners from under-represented groups see a future for themselves in STEM education and industries. Informed by a growing body of research addressing STEM equity activism (see Kokka, 2018; McGee, 2023; Miller et al., 2021) our attention turns to the experiences of pre-

service teachers as activists. In this context, STEM education activism is a means of advocating for improving and increasing access to high-quality, inclusive STEM education and promoting diversity in STEM fields. This purpose of this research is to examine how the facilitation of inclusive STEM outreach impacts pre-service teachers' perceptions of themselves as activists.

It should be noted that *STEM education* is open to a range of interpretations. In Hasanah's (2020) comprehensive literature review of the definitions of STEM education, it was concluded that the definition is contingent upon the stakeholders and their context. In a 2020 position paper, the National Science Teachers Association (2020) defined STEM education as an "experiential learning pedagogy in which the application of knowledge and skills are integrated through in-context projects or problems" (para 1). The STEM Explorers project most closely aligns with this interpretation as it does not tether itself to a traditional notion of STEM education as an amalgamation of 'host' disciplines and their associated content, skills, and processes. Instead, it proposes a meaningful integration of situated learning experiences. In turn, the STEM Explorers activity stations are designed to tap into the crosscutting skills that transcend specific disciplines. Highlights offered in 2024 include an exploration of skilled trades in agriculture while tending live farm animals, experimenting with digital music production and sound transmission by building a potato piano, and learning about chemistry and skin health while creating cosmetics using natural ingredients.

Research Context: STEM Outreach

A Faculty of Education in Ontario, Canada has taken a novel approach to inclusive STEM education through outreach. STEM outreach involves the delivery of STEM content outside the traditional classroom to enhance understanding, awareness, and interest in STEM (Tillinghast, 2020). The *STEM Explorers* outreach project focuses on reducing barriers children and their families face in accessing high-quality extracurricular STEM experiences. The three-year project (2023-2025) involves free in-community STEM education outreach events at board-identified schools with a higher proportion of students who are Black, Indigenous, and from other equity-deserving groups. Through afterschool 'pop-up' STEM festivals, STEM Explorers has reached over 2,200 children and 1,000 adult family members in its first two years of operation. Students from the University play a central role in the project by serving as the STEM Explorers Facilitators (SEFs). SEFs research, plan, pilot, and lead high-interest hands-on activities in activities focused on integrated STEM skills.

STEM Explorers is informed by a substantial body of research indicating that these types of extracurricular experiences positively influence students' future interest in STEM careers (Steenbergen-Hu et al., 2017; Mtika, 2019; Stringer et al., 2019). In addition, children from under-represented populations tend to participate more often in STEM outreach events compared to other students (Afterschool Alliance, 2009). Ludwig and colleagues have concluded that this type of research-based informal STEM programming requires minimal resources, is scalable, and can improve marginalized student outcomes (2024).

STEM Outreach as Activism

The merits of serving as facilitators in STEM outreach initiatives are well documented in the literature. Post-secondary students who have served as STEM outreach leaders self-reported that participation had a positive impact on their personal, academic, and professional development (Saville & Jakobi, 2022). Involvement in STEM outreach can improve pre-service teachers' engagement, sense of efficacy, and teaching of STEM (Kim et al., 2015; Beriosha & Vula, 2021; Chalmers, 2014; O'Dwyer et al., 2023). Studies examining the STEM outreach facilitator experience indicate there is alignment between their experiences and humanitarianism, community development, and sustainability (Litchfield & Javernick-Will, 2015; Anagnos et al., 2014). Although the facilitation of inclusive STEM outreach experiences by pre-service teachers can be regarded as a form of activism (Kokka, 2018; Velasco, 2023), there is still limited scholarship in terms of how they see their impact as activists within a larger social, political, and ideological context (Popkewitz, 2018). Miller and colleagues call for ongoing awareness raising, research, and professional learning to address teacher activism in the STEM fields (2021). This qualitative research serves to address this gap in the literature by examining the experiences of pre-service teachers in inclusive STEM outreach programming as a form of activism.

STEM Outreach Facilitator Experience

The SEFs are post-secondary students, the majority of whom aspire to be K-10 teachers in the future. Most possess at least one undergraduate degree and are enrolled in pre-service teacher training in the University's Bachelor of Education program. A smaller number enrolled in their initial BA or BSc degree. Each year, approximately 40 students are recruited to serve on the STEM Explorers facilitator team. The role is advertised through a range of recruitment channels and applicants from equity-seeking groups were encouraged to apply. STEM Explorers focuses on reflecting the diversity of the community being served by representing ranging perspectives and lived experiences in the facilitation team. Students who identified as Black, Indigenous, racialized, having disabilities, and 2SLGBTQ+ represented 50% of the students hired. Not only did they bring high caliber skills to the project, but the intention was that participating children and adults would acknowledge and value the representation.

The SEFs receive training focused on culturally inclusive pedagogies and community-responsive STEM programming. Faculty members, community partners, and an advisory panel provide further mentorship. The facilitators are required to learn about the community they will serve before they begin planning the hands-on activities. This culturally responsive approach invites openness, community involvement, and the interconnection of home, school, and the outreach project (Burke, 2019). For pre-service teachers, informal STEM education experiences like these provide invaluable targeted science teaching practice (Luehmann, 2007). STEM Explorers is intended to encourage sustained interest in STEM, not only for participating children and their families but, importantly, also for the SEF team. Teacher participation in STEM outreach activities helps teachers develop their own sense of identity as STEM professionals

(Aslam et al., 2018). Marotto (2018) reported the experience increased their content knowledge, awareness of effective STEM pedagogies, and helped put theory into practice.

METHODOLOGY

The purpose of this phenomenographic study was to explore the experiences of pre-service teachers as STEM outreach facilitators to better understand the unique ways that outreach initiatives like STEM Explorers in particular, impact pre-service teachers' views of activism, advocacy for equitable access of STEM education for under-represented groups.

Phenomenography, as a methodological paradigm, emphasizes personal conceptions as important constructs (Feldon & Tofel-Grehl, 2018). The approach aims to "investigate the qualitatively different ways" we can understand a particular phenomenon or aspect of the world around us (Marton & Pong, 2005, p. 335). In this research, we seek to understand how pre-service teachers develop their personal meanings of equitable STEM education and activism. We hope to reveal factors that influence their cognitive frames and provide evidence of participants' shifts in thinking in relation to social action and change (see Straub & Maynes, 2021, p. 72)

Phenomenography assumes a limited number of ways that pre-service teachers can relate to conceptual understanding. In this case, the role of the researchers was to categorize the differences found in these experiences (Åkerlind, 2005; Marton, 1992). Phenomenography does not rely on predetermined categories but uses hierarchical categories that are determined by participants' responses which may allow for a greater understanding of equitable STEM education through an activist lens. It also shows connection to its related conceptions of the topic under study. According to Straub and Maynes (2021) "once the different ways participants understand a concept and how it is uncovered becomes clear, a deeper understanding of what takes place" when individuals are thinking about a concept will likely emerge (p. 72).

The phenomenographic approach has been applied in a small number education research contexts that explore pre-service educators' experience of STEM outreach (see Schill, 2021; Acero et al.; Velasco & Hite, 2023). This research serves to expand upon this burgeoning field of scholarship by how examining STEM outreach facilitation opportunities as a form of activism.

Methods

This research analyses the experiences and perspectives of STEM outreach facilitators currently enrolled as university students. Following research ethics board approvals by the University, a call was put out for potential research participants from the 43 SEFs involved in the 2023 STEM Explorers program. Information about the project and an informed consent form was shared by email. Through voluntary sampling, 10 of the SEFs gave their consent to be part of the research. One faculty member who volunteered as an SEF also participated in the research.

Semi-structured interviewing is central to this type of study of social movements, enabling the researcher to better understand the motives and activities of those who

participated (Blee & Taylor, 2002). The research team developed an interview guide in advance that gave SEF participants an opportunity to describe and reflect upon their STEM Explorers experience. The opening question asked participants to create a concept map on paper to help them recall important parts of their STEM Explorers experience and organize their ideas. They were encouraged to refer to the map throughout the interview but were not required to share it with the researchers. Subsequent questions addressed their personal definitions and experiences with STEM, motivations for joining STEM Explorers, and descriptions and reflections of the experience. They were also asked how involvement in STEM Explorers influenced their self-perception and teaching abilities in STEM, particularly regarding under-represented groups.

The interviews were 45-60 minutes in length and conducted using video conferencing software, audio recorded, and transcribed. The researchers reviewed the transcripts for accuracy, the data was de-identified and anonymized, and participants were given the opportunity to conduct individual members check for accuracy. The prepared texts were divided amongst the team and closely read to initiate an inductive thematic analysis (Miles, Huberman, & Saldaña, 1994). As concepts became apparent, relevant sections of text were identified and analytical memos were recorded. Through a constant comparative approach (Glaser, 1992) codes were noted, linked to relevant text excerpts, and continually refined and merged to generate general categories. In line with Richards and Hemphill's (2018) approach to collaborative qualitative analysis, the research team met regularly, discussed and amended the initial codes and categories, and reached consensus on the coded data. Through this inductive process, three key themes emerged from the data analysis.

RESULTS AND DISCUSSION

Evolving STEM Identity

Possessing a STEM identity involves being recognized as a *STEM person* by oneself and others (Carlone & Johnson, 2007). When one possesses a STEM identity, they "see themselves as the kind of people who could be legitimate participants in STEM through their interest, abilities, race, gender, and culture" (Hughes et al.,2013, p. 1980). Its development helps people recognize applications of science in their daily lives and have a more active and concrete understanding of STEM (Wade-Jaimes et al., 2021; DeWitt & Archer, 2017). The STEM identity is nurtured when people experience engaging and satisfying STEM experiences, reinforcing continued interest, participation, and learning (Center for the Advancement of Informal Science Education, 2018).

In this study, all participants indicated that the development of their STEM identity did indeed progress as a result of their participation in STEM Explorers. As noted by "Sorel",

"I've kind of said throughout this, I didn't fully see myself as a STEM person and now I can kind of see it a bit closer now instead of being like that's a distant far thing that I didn't think would happen."

Sorel's comment encapsulates the sentiments of her fellow participants in that prior to the STEM Explorers experience they were reluctant to regard themselves as a STEM person.

Those with non-STEM academic backgrounds, such as Sorel, were much more likely to not see themselves as STEM people at all. Even those with prior degrees in a STEM field did not fully see themselves as having a well-developed STEM identity. One such participant, “Joshi”, expressed how “STEM was...not to say not my field, not my field of *strength*”.

Similarly, “Kay” indicated that their involvement in STEM Explorers helped confirm their STEM identity in that “before, I definitely did [identify as a STEM person] but I don't know that I could have verbalized it without this project… this experience refined how I viewed myself and also just kind of shifted it a little bit”.

Most participants described how their involvement in STEM Explorers influenced their identity formation specifically as a *STEM educator*. “Meg” felt the experience gave them greater breadth in their teaching abilities. They said,

“I think what I see myself as now is a much more well-rounded educator. I don't necessarily see myself as a pure STEM educator, but I definitely see myself as a much more rounded educator who is able to use STEM teaching tools.”

> “Eriksa” described how their involvement in the project helped them realize their own capacity and potential as a STEM educator.
>
> …before I didn't think of myself as having the expertise needed to be a science teacher. But you know, science isn't everything in STEM. I think I feel more like I can be one [STEM educator] now. At the very least, working at STEM Explorers showed me that a lot of the things that elementary school kids are learning in STEM are things that I could teach. And also, it showed me that there's a lot of different initiatives that support teachers in equipping themselves with what they need to teach those things. So, I think I definitely didn't before, but I feel more inclined that I could be.”

Meg’s and Eriksa’s comments are resonant as teachers with a positive STEM identity are more likely to foster positive STEM identities in their students (Giles et al., 2023; Martin-Hansen, 2018). Early STEM experiences for children can be impactful in the development of a positive STEM identity in the future and can also influence their career choices in the STEM fields (Cohen, et al., 2021; Martin-Hansen, 2018). Furthermore, teachers who have a positive STEM identity are more likely to use innovative and inclusive teaching approaches and be advocates for STEM education (El Nagdi et al., 2018; Hite & Milbourne, 2024).

Serving as facilitators with the STEM Explorers outreach project enhanced the SEFs view of themselves as STEM people and STEM educators and the potential for working towards positive change in society. As suggested in the interview excerpts provided, this transformation was often reported with a degree of tentativeness. Although the data does reveal that the SEFs placed value on a positive STEM identity, it is difficult to pinpoint which aspects of their involvement left the deepest impressions on the SEFs. In light of the merits of a positive STEM identity in educators, this points to an area requiring significant further investigation.

Integrated and Student-centered STEM Learning

Nadelson and Seifert (2017) define STEM learning as "the seamless amalgamation of content and concepts from multiple STEM disciplines" (p. 221). This type of integrated STEM learning is less focused on siloed STEM disciplines and more on "crosscutting concepts and real-world applications" (Kelley & Knowles, 2016, p. 1). The integration of STEM cognitive processes such as observing, measuring, classifying, describing, analyzing, and synthesizing are also key (Cheng & Winnie Wing, 2020). In a systematic literature review of the literature, Le and colleagues concluded that integrated STEM approaches were effective in improving associated outcomes for K-12 students including students' learning achievement, higher-order thinking skills in science, and interest in STEM careers (2023). In creating high quality, equitable, and accessible STEM learning experiences for all children, integrated STEM approaches play a significant role.

Most participants expressed that through their participation in the project, they were better able to understand how STEM could be viewed, not as separate disciplines but, as Jasmine put it, "quite connected with each other". Jasmine went on to say that "STEM to me would be instead of individualizing each section, [it] would be more about how we connect everything together to create some amazing lessons and activities that students could experience". Confidence to integrate STEM with other subject areas was also revealed. At first, some saw STEM as being primarily related to science and technology but what they realized after their involvement was how STEM can be integrated into other disciplines. Meg understood this in this way:

"It definitely is more connected…science, technology, engineering and mathematics…I didn't always see the connection between these and other subjects. Now I can see that there's relatively easy ways to connect it to other things like any of the arts or language. It's kind of in everything." (Meg, 2024)

There is evidence that the SEFs recognized specific approaches to achieve the integration of STEM learning. Eriksa stated that the STEM Explorers approach was more open-ended as "we're not reading to or talking at the kids" but providing children with multiple opportunities to "muddle" through and solve problems. Joshi had a more nuanced understanding as indicated by their comment that "within STEM Explorers comes the idea of transferable skills and the idea of curiosity through inquiry".

Student-centered STEM learning can have a significant impact on students' engagement and can enhance student success and decrease social disparities in STEM education (Struyf et al., 2019; Johnson, 2019). Research further indicates that *hands-on* STEM learning can significantly benefit diverse learners by enhancing engagement, critical thinking, and social learning (Strayhorn et al., 2014; Boakes, 2019). Several participants noted the importance of this type of learning. Jasmine said, "I think the best STEM learning is hands-on. I am a very hands-on learner, so it makes the most sense to me. There's just different things in your brain that are working and pushing you to think differently."

Eriksa shared Jasmine's sentiment and provided a detailed example as to how the hands-on component lowered barriers for some learners.

> "There is a need for students to have something hands-on to do. Just talking at them does not teach them even a fraction of what they learn from just getting their hands on something and doing it. And STEM Explorers really taught me that, I think, because I could see how much they were learning and thinking. When I'd explained what a sound wave was, I could tell they didn't really get it but then I'd get them to make the sound wave in the water with the tuning fork and then with the spring, and they're like, "Oh, I know what that is. I know what it does." So, I could ask them, "How do you think this string telephone works?" and they could contribute. So just having those valuable hands-on experiences drew people in."

Integrated and student-centered STEM education can significantly enhance the STEM learning experience. Participants in the STEM Explorers project understood the value of the interconnectedness of STEM disciplines and student-centered learning. Adopting such approaches are essential for creating equitable and effective educational experiences that prepare students for future STEM career.

Activist Purpose

Possessing a positive STEM identity and being prepared to teach a high-quality integrated STEM program are essential if pre-service teachers are to see themselves as STEM education activists. However, as asserted by Ollis (2012), possessing a *sense of purpose* is a vital motive for engaging in activism. The activist purpose describes individuals who participate in goal-oriented behaviors related to activism and the building of social change (Wilson & Hill, 2023). This sense of purpose is a feeling that the work is significant, purposeful and contributes to others (Burrow & Hill, 2020). All our research participants were able to articulate how the SEF experience fostered a sense of purpose. Some explained the sense of purpose as a more collective experience. While the overall purpose of the project was well articulated in the pre-season SEF training sessions, the interviewees were able to describe a much more personal and nuanced sense of purpose. For example, Sorel noted,

> "All those kids that experienced the stuff that we did probably won't forget that ever. They'll remember the person [SEF] who said they could be a scientist, the person showed them how circuits work, or that person who showed me how to dig up fossils out of the dirt. In those kids lives, all those little events are so unique and so different to the typical day that they would have at school. I feel like it would help them to like realize that, 'Right - this is a possibility for me.' There are more possibilities than what maybe other people are saying I have."

Limitations and Implications

Sociodemographic data was not collected ahead of or during the interviews as with a small sample, it was important to maintain the anonymity of the participants. In hindsight, this

omission is a limitation of the findings. In particular, age, ethnicity, and gender identity were addressed in the interviews, but unfortunately no systematic analysis of these factors can be provided.

Creating opportunities for pre-service teachers to engage in work that serves as a vehicle for societal transformation through an activism lens is challenging. As impactful as the STEM Explorers project is, some research participants commented that the STEM Explorers was not a sustainable way to reach children from under-represented groups and in turn, a way to help foster STEM education activism.

Pre-service teachers certainly benefited from participating in this research project by having the opportunity to reflect on their own motivations for engaging STEM outreach as activism. While most TCs expressed a change in their identities and grew in their understanding of how STEM can and should be taught, some TCs may continue to hold naive conceptions about a teacher's role as activist within a larger social, political, and ideological context (Popkewitz, 2018). For outreach initiatives such as STEM Explorers to assist in attending to teacher candidates' conceptions of privilege and their understanding of rights for minority groups leading to social action and social change, more should be done to uncover the conceptions they hold prior to the events to ensure that all TCs understand how STEM can serve all communities.

CONCLUSION

It is important for pre-service teachers to understand the role they play in advocating for equitable access to high quality and inclusive STEM learning opportunities for all students. This study explored how one group of pre-service teachers who served as STEM outreach facilitators, clearly identified how their identities as STEM educators shifted due to their participation in STEM Explorers. Through their participation, their overall understanding of how to teach student-centered and integrated STEM evidently developed in sophistication. However, within a larger social, political, and ideological context, their identities as activists remain less clear. Through this initiative, the pre-service teachers expressed a keen interest and enthusiasm for STEM which may continue to lead them to a deeper understanding of their role as social agents. More research needs to be conducted to discern the affordances and barriers to their development as STEM education activists and also to provide supports that foster reflective practice.

The overarching goal of this phenomenographic study was to better understand the ways that STEM outreach initiatives can bring about tangible impacts on educational practices in teacher education. By creating opportunities for pe-service teachers to engage in this type of work, they can better appreciate their ability to work towards societal change through activism. By reflecting on their own motivations and teacher practice, and by exploring their experiences, teacher candidates can apply their learning to advocate for equitable and inclusive STEM education and future opportunities.

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