Volunteer Educators' Perceptions of Mentorship Involvement: Grades 9-12 Robotics

by

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A thesis submitted to the
School of Graduate and Postdoctoral Studies in partial
fulfillment of the requirements for the degree of

Master of Arts in Education

Faculty of Education

University of Ontario Institute of Technology (Ontario Tech University)

Oshawa, Ontario, Canada

December 2023

Thesis Examination Information

Submitted by: **Katlin Walsh**

Master of Arts in **Education**

Thesis title: Volunteer Educators' Perceptions of Mentorship Involvement: Grades 9-12 Robotics

An oral defence of this thesis took place on November 29, 2023, in front of the following examining committee:

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Chair of Examining Committee	Dr. Ann LeSage
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The above committee determined that the thesis is acceptable in form and content and that a satisfactory knowledge of the field covered by the thesis was demonstrated by the candidate during an oral examination. A signed copy of the Certificate of Approval is available from the School of Graduate and Postdoctoral Studies.

Abstract

As non-educators increasingly support volunteer-based STEM programs, adopting pedagogically aligned mentorship training is required to support developing and retaining subject-specific mentorship practices and volunteer engagement with equity, diversity, and inclusion in STEM communities. This research aimed to understand how informal educators develop their personal mentorship practice and investigate volunteer's understanding and engagement with equity, diversity, and inclusion within competitive *FIRST* robotics competition teams.

Using a qualitative, collective case study, eight volunteer mentors participated in virtual interviews, using constructed personal artifacts for self-reflection and presentation, concluding the 2021-2022 mentorship season. A conceptual framework of constructionism, project-based learning, and communities of practice guided this study, using an inductive thematic analysis process to interpret the findings. The study's results highlight that artifacts guided mentors' communication related to mentorship as a practice and increased acts of authentication through subject-specific language.

Keywords: mentorship; volunteer; FIRST Robotics Competition; STEM; OST club; equity diversity inclusion.

Author's Declaration

I hereby declare that this thesis consists of original work of which I have authored. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Katlin Walsh

Statement of Contributions

I hereby certify that I am the sole author of this thesis and that no part of this thesis has been published or submitted for publication. I have used standard referencing practices as outlined in the *Publication Manual of the American Psychological Association, 7th Edition* (American Psychological Association, 2020) to acknowledge ideas, research techniques, or other materials that belong to others. Furthermore, I hereby certify that I am the sole source of the creative works and/or inventive knowledge described in this thesis.

Acknowledgments

Thank you to my research supervisor, Dr. Janette Hughes, for your continued guidance. My participation in Dr. Hughes' STEAM-3D Maker Lab has been a wonderful place to grow my practice as an educator and to contribute to a community during my graduate studies. Thank you also to the committee who have taken the time to review and take an interest in my thesis, including Dr. Diane Tepylo and Dr. Annie Savard. Your feedback, comments, and encouragement throughout this process have been integral.

I'd like to express my unwavering gratitude to every mentor who spoke with me, especially the eight who agreed to participate in this study. You inspire me! I truly appreciate your continued engagement in asking questions about educational theories, sharing your mentorship resources, and providing feedback on the study's progress. Thank you for trusting me to share your story. I'd also like to thank the organizers of the 22 FLL, FTC, and FRC events in Ontario that I attended as a volunteer in 2022, who supported me in sharing information about my study with mentors attending events during the study's recruitment phase.

Thank you also to the late Dr. Woodie Flowers for inspiring me to explore graduate-level education. Our conversations about travel, photography, and volunteerism gave me the courage to continue the pursuit of creative expression while juggling full-time studies and working as a professor. You inspired me to investigate how to make teaching and mentorship more accessible, fun, and engaging.

Thank you to all my friends and family who have accepted me as I am. Thank you for creating safe spaces for my research while we were at scoring tables, cottages, campsites, long weekends, offices, living room couches, trains, buses, planes, backyards, hotel rooms, decks, and patios. Thank you for your understanding and support throughout many conversations during the past three years and for helping to encourage balance.

Jamie. Thank you for being on my team every single moment of this journey. Thank you for helping me continue supporting my volunteerism and mentorship and encouraging me to advocate for accessibility and representation instead of limiting my participation. Thank you for being a sounding board, hyping me up, and sticking with me while I explored graduate education. Your support has never wavered for a single second.

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List of Abbreviations, Definitions, and Symbols

2SLGBTQI+	Two-Spirit, Lesbian, Gay, Bisexual, Transgender, Queer, Intersex, Plus other sexual and gender diverse communities
CoP	Communities of Practice
EDI	Equity Diversity and Inclusion
FIRST	For Inspiration and Recognition of Science and Technology
FIRST Alumni	Graduate of grade 12 who have spent at least one season as a participant on a *FIRST* Robotics Competition or *FIRST* Tech Challenge Team.
FLL Challenge	*FIRST* LEGO League Challenge - age 4 - 16 robotics league, 2-10 students per team.
FRC	*FIRST Robotics Competition - age 14 - 18 robotics league, approximately ten or more students per team.*
FTC	*FIRST* Tech Challenge - age 12 - 18 robotics league, 2 - 15 students per team.
Kickoff	Kickoff sparks the start of the *FIRST* Robotics Competition season. On the first Saturday in January each year, teams are presented with a game animation and full rule manual of the annual challenge.
Lead Mentor	Primary or secondary mentor of a *FIRST* Team. In addition to mentoring, manages mentor recruitment, finances, and administrative tasks annually.
LPP	Legitimate Peripheral Participation
LRI	Lead Robot Inspector
MIT	Massachusetts Institute of Technology

OST	Out-of-School-Time
PBL	Problem-Based Learning
PjBL	Project-Based Learning
SES	Socioeconomic Status
STEM	Science, Technology, Engineering, and Mathematics
TGNC	Transgender, Non-Binary, and Gender Nonconforming

1 Introduction

This research explores the intersection of informal youth mentorship and inclusive community development practices for STEM programs like the *FIRST* Robotics Competition. Research studies investigating educational robotics have steadily increased since the early 2000s (Anwar et al., 2019). Researchers such as Dolenec et al. (2015) have described the numerous youth benefits of participating in informal, low-stakes education settings, which primarily occur in out-of-school-time (OST) settings. Regardless of the subject, youth programs provide a space to develop relationships informally with adult mentors, whose focus is to design and maintain socially safe environments for youth. Researchers have found that mentor/mentee relationships are most effective in supporting youth after at least 24 weeks of mentorship (Aresi et al., 2020). Youth program mentors support mentees through experiential activities, such as hands-on projects, that naturally build relationships between a youth and adult mentor (Aresi et al., 2020; Davis et al., 2021; Koomen et al., 2021).

General studies investigating outcomes of youth STEM programs in informal and educational settings have also documented chronic overrepresentation of Caucasian men participants (e.g. Burack et al., 2019; Meschede et al., 2022; Yoel et al., 2020; Witherspoon et al., 2018), and their informal educators (e.g. Hennessy Elliott, 2020; Powers et al., 2015; Verma et al., 2015). These findings align with continued calls for equity, diversity, and inclusion efforts in post-secondary institutions and the workforce. Investigations into supporting underrepresented youth STEM programs from a lens of singular (e.g. women in STEM) or dual identity (e.g. Latinx women in STEM) studies have been crucial to gaining critical insights into how students can be supported in closing the STEM gap. As students participate in youth STEM programs such as FRC, they form a sense of belonging to a larger community.

The development of communities of practice (CoP) served as a lens for this study. Communities of practice are created naturally by groups who share a common interest in a subject and practice those interests as a community over time (Verma, 2015). In the context of a youth STEM program such as *FIRST*, mentors and students contribute to the growth of a team, forming a community of practice (e.g., Davis et al., 2021; Hennessy Elliott, 2020; Koomen et al., 2021; Verma, 2015). Team members demonstrate their integration in a community of practice through acts of authentication through technical language specific to the *FIRST* program. This study explores the construction of communities of practice, and the language mentors use to describe practicing communities. In educational research, formal educators describe the use of pedagogical approaches to co-construct communities of practice, of which the integration of a member into the community is evaluated by their ability to utilize subject-specific language (Verma, 2015) authentically. Several empirical studies and literature reviews document practitioner best practices for the development of informal youth STEM programs (Anwar et al., 2019; Davis et al., 2021; Dwivedi et al., 2021; Jin, 2021; Ozis et al., 2018; Witherspoon et al., 2018). While informative, professional volunteers with limited formal educational training face barriers to the accessibility of language in pedagogical and theoretical publications.

This study illustrates eight mentors' experiences as informal STEM educators to FRC teams across Ontario. The creation and design of this study document mentors' construction of inclusive *FIRST* teams, which have been formally defined in educational research as a community of practice (Davis et al., 2021). Guided by pedagogical frameworks rooted in educational research, I sought to identify best practices common to practitioner reports to forward understandings of informal STEM clubs, regardless of a mentor's formal education and use of pedagogical theory to describe their educational practices. As FRC mentors, the participants aimed to support the high school robotics team's participation in the 2021-2022 FRC season, which concluded in the Province of Ontario through the Ontario Provincial Championship Event. This collective case study was situated in constructionism, informing the findings' development, analysis, and presentation of the findings. Building off the numerous pedagogical benefits afforded by OST STEM clubs, this study seeks to chronicle how adult mentors design and maintain socially safe environments for youth programs such as FRC teams, regardless of a mentor's professional experience in education. Through collective case studies, this study provides a detailed description that chronicles the construction of inclusive youth STEM communities.

1.1 *FIRST* Robotics Competition (FRC)

FIRST (For Inspiration and Recognition of Science and Technology) is an international non-profit organization founded in the United States in 1989 whose mission is to "inspire young people to be science and technology leaders and innovators by engaging them in exciting mentor-based programs that build science, engineering, and technology skills, that inspire innovation, and that foster well-rounded life capabilities including self-confidence, communication, and leadership" (FIRST, 2022a). The *FIRST* Robotics Competition (FRC) program uses project-based learning (PjBL) for students in grades 9-12 guided by mentors who serve as informal educators. Each year, students must compete to create a robot within a strict set of rules themed around a socially relevant challenge, such as transportation (FIRST, 2022a), to complete program tasks. *FIRST* is the world's most extensive non-profit competitive youth program (FIRST, 2022a), serving 534,000 participants from K-12 from 98 countries in the 2021-2022 season (FIRST, 2022b).

Woodie Flowers was a significant contributor to *FIRST*'s ethos and founding principles, serving as a Distinguished Advisor to the organization until he died in 2019. As a Professor Emeritus at MIT, Dr. Flowers worked with Seymour Papert, reviewing one of Papert's doctoral supervisions (Martin, 1988) and presenting at MIT's Tech Days (Sales, 1997). Indeed, Papert's theoretical development of constructionism and work with the LEGO group to create the educational robotics tool LEGO Mindstorms was globally launched through the partnership of *FIRST* LEGO League Challenge (FLL Challenge) in

September of 1998 (Ames, 2018; Benjamin, 2023). *FIRST* programs from K-12 remain aligned with theories of constructionism today through the organization's continued use of project-based construction to produce artifacts of learning with the support of educators.

FIRST has acknowledged historical society-level gaps in access to STEM education for youth. It has several initiatives surrounding Equity, Diversity, and Inclusion (EDI), primarily focused on the support of American-based teams. EDI initiatives have included (a) core values and team-based awards targeting inclusion of underrepresented groups, (b) optional mentor training and micro certifications for EDI, which cover considerations for teams and fellow mentors, (c) financial compensation for teams and individuals representing Indigenous, low-income (e.g. schools with 40% or greater of the student population on free & reduced lunch programs), and women and (d) publications of blog posts and social media campaigns encouraging participation of racial minorities and women in STEM (Center for Youth and Communities, 2011).

While EDI efforts have been made at the program level for American-based teams, there are significant gaps for increased engagement of underrepresented groups at the team and program levels. One variable to focus on is the representation of mentors and volunteers in STEM programs. *FIRST*'s primary focus has been on the research and documentation of the impact for youth graduates entering into postsecondary and professional STEM-based fields in comparison to (a) competitor youth STEM programs such as VEX and Science Olympiad and (b) control groups who do not participate in high school STEM programs. Indeed, *FIRST* alumni, particularly women, have higher computer science and engineering confidence levels (Burack et al., 2019; Meschede et al., 2022) compared to other programs.

In contrast to youth outcomes, very little documentation about the qualities, training, and benefits of *FIRST*'s volunteer mentors is available. Some publications from an FRC program review illustrate that *FIRST*'s mentor demographics are primarily middle-aged Caucasian men who mentor (Center for Youth and Communities, 2011; Hennessy Elliott, 2020; Powers et al., 2015; Verma et al., 2015), mirroring both Canada's (Hahmann, 2021) and the United States (Americorps, 2023) reports on volunteer coach/mentor demographics. This study seeks to bridge the gap by identifying informal educators' approaches to mentorship and documenting their unique and multifaceted identities concerning STEM. Although this will not solve the retention problem of underrepresented groups in STEM, it will provide a starting point that identifies approaches to teaching and learning in informal STEM settings.

1.2 Positionality Statement

As a STEM professional, I have navigated barriers surrounding my gender, age, sexuality, income, invisible and visible disabilities, and level of education, especially while I held key leadership positions. Though I identify as a woman and have personally experienced barriers related to the historic gender gap in STEM (Burack et al., 2019; Hennessy Elliott, 2020) and as a technical youth program volunteer (AmeriCorps, 2023; Hahmann, 2021), it is a singular part of my multifaceted identity. This research aims to better understand multifaceted identities and how people historically underrepresented in STEM develop their identity through participation in programs such as FRC.

Both my own beliefs and the beliefs of the founders of the *FIRST* Robotics Competition (FIRST, 2016) program are rooted in the constructionist lens that situated the research project. As an alumna of an FRC team, I have experienced barriers to equitable participation in STEM as a student, a mentor, and an event volunteer. I have been recognized with several team-based and individual awards for my commitment as a volunteer and mentor to the *FIRST* program over the past ten years. I have served on several volunteer committees that have shaped the *FIRST* program globally, where I have supported the progression and accessibility of programs from K-12. As a Lead Mentor for two FRC teams, I have annually mentored 50-200 students and trained new mentors technically and non-technically.

Professionally, I have spoken at several informal conferences about my lived experiences and have suggested ways of supporting *FIRST* teams and events in more inclusive spaces. I recognize my privilege in the ability to pursue higher education at the graduate level, as well as my Caucasian English-Irish-Scottish heritage and its role in the historical oppression and mistreatment of Indigenous Canadian people. I regularly communicated with research participants throughout the research process and worked with peers and supervisors to respectfully amplify the voices and stories of participants in the study.

As the primary designer and researcher of this study, my background and experiences have shaped the analysis and presentation of this thesis. As a Master's student at Ontario Tech University, I have completed graduate-level studies in theoretical frameworks and research methodologies in education. Throughout the process of this research, I have been supervised by Faculty and researchers with strong backgrounds in educational research. As a graduate of an Honours Bachelor of Interaction Design with a minor in Creative Leadership, I have a strong background in the design and execution of project-based learning in STEM fields. I am both personally and professionally interested in how informal educators apply and communicate mentorship techniques, as well as how communities in STEM programs are built to become more inclusive, which inspired the topic of study.

1.3 Research Goal

This qualitative case study aims to understand the lived experiences of eight volunteer STEM mentors and their construction of inclusive spaces for youth. Mentors detailed the support teams of *FIRST* Robotics Competition (FRC) students in grades 9-12 who competed in the 2021-2022 FRC Ontario Provincial Championship event from April 13-16, 2022. All participants were interviewed virtually between April 27 and June 1, 2022, after the FRC competition season officially ended.

This thesis aimed to investigate the ability of informal educators to describe their pedagogical approaches to STEM programs and their development of inclusive STEM communities. In particular, the intersection of informal educators and described approaches for including students and educators in STEM youth programs from a critical lens was a topic of interest. In this research, the FRC served as the medium for mentors to describe the construction of their educational practices. The research aimed to investigate the following questions:

1. How have individual participants' mentorship approaches of grade 9-12 robotics teams evolved throughout their time as mentors?

2. What approaches do mentors use to develop a sense of community, particularly for underrepresented populations participating in grades 9-12 competitive robotics teams?

1.4 Thesis Organization

In this chapter, I provided an overview of the research topic, an overview of the *FIRST* Robotics Competition (FRC) and research considerations (1.1), followed by my position as a researcher (1.2). I also provided an overview of the research goal (1.3), including the questions guiding the study. The remainder of this thesis is organized in the following chapters:

Chapter Two provides an overview of trends in the literature on the critical themes of volunteer mentorship and youth STEM clubs. First, I broadly define volunteer mentorship (2.2) with trends in both Canada and America, followed by an overview of youth program mentorship (2.2.1). I then share volunteer motivations to mentor (2.2.2) and professional development considerations for youth mentors (2.2.3). In the second central section, I summarize the literature on youth STEM programs (2.3), highlighting variations between competitive STEM programs (2.3.1), followed by approaches to competitive youth mentorship (2.3.2). I conclude this section by diving into intersectionality in STEM programs (2.3.3). Following these themes, I investigate limitations and gaps in existing research (2.4), followed by the research questions (2.5) guided by the literature. I conclude the chapter with an overview of the theoretical framework (2.6) underpinning this study. Constructionism (2.6.1), project-based learning (2.6.2), and communities of practice are foundational to the history and operation of youth STEM programs, guiding the study's design. Finally, I conclude the chapter by illustrating the conceptual framework underpinning the study's design and analysis (2.7).

Chapter Three documents the research methods and design of the study. First, I introduce the research design (3.2.1), followed by a review of the overall design and structure of the *FIRST* Robotics Competition (FRC) program (3.2.2). I then detail the participants and recruitment criteria of the study (3.3), followed by a description of the virtual context in which the study took place (3.4). I describe the four sources of data collected for the study (3.5) and its ethical measures (3.6) and conclude with my six-phase approach to data analysis (3.7).

Chapter Four illustrates the findings of the study organized by its research questions. I first analyze participants' mentorship approaches concluding the 2021-2022 FRC season (4.2) before describing three selected cases (4.2.1) in greater detail. I then explore ways mentors develop an FRC community (4.3), expanding four cases that exemplify community development approaches in greater detail (4.3.1). I conclude the section by summarizing findings (4.4) and providing a cross-case analysis of each theme.

Next, Chapter Five connects the study's findings to the existing body of literature. I discuss the collective lived experiences of mentors (5.2) concerning their motivations, experienced barriers, and the progression of their mentorship application, followed by their approaches toward the development of FRC communities (5.3).

To conclude, Chapter Six summarizes the study's limitations (6.1), suggests areas for future research (6.2), and highlights potential educational implications (6.3). Finally, I conclude (6.4) by connecting the study's findings with previous literature and the conceptual framework underlying this thesis and supporting recommendations for the future of youth STEM program mentorship.

2 Literature Review & Theoretical Framework

2.1 Overview

Since the early 2000s, there has been a steady increase in empirical research studies investigating the impact of educational robotics on youth outcomes (Anwar et al., 2019). Across the literature, robotics programs outside of the traditional classroom environment are classified as out-of-school-time (OST) programs, which rely heavily on the mentorship of adult experts who donate their time as program volunteers to promote informal learning (Dolenec et al., 2015). OST learning environments often take a relaxed pedagogical approach, which provides youth with highly valued information-rich opportunities in an informal learning environment (Aresi et al., 2020; Davis et al., 2021; Koomen et al., 2021; Witherspoon et al., 2018). The creation of low-stakes and socially safe youth program environments is facilitated by continued mentor training support of subject-specific (Dwivedi et al., 2019; Franck & Donaldson, 2020; Jin, 2021; Kekelis et al., 2017), pedagogical facilitation (Cicchinelli & Pammer-Schindler, 2022; Franck & Donaldson, 2020; Jin, 2021; Kekelis et al., 2017; Powers et al., 2015), and authentic equity, diversity, and inclusion (EDI) engagement (Kekelis et al., 2017; Powers et al., 2015).

Science, Technology, Engineering and Math (STEM) clubs target the development of subject competencies, career choices after high school, self-efficacy, and interpersonal skills (Witherspoon et al., 2018). High school STEM clubs operate in various forms, including classroom-based, after-school, community, camps, and maker spaces. Demographically, there is a historical overrepresentation of Caucasian men of a high socioeconomic status (SES) in STEM. Across the literature, this overrepresentation is present both for youth participants (e.g. Burack et al., 2019; Meschede et al., 2022; Witherspoon et al., 2018; Yoel et al., 2020) and volunteer mentors (e.g. Hennessy Elliott, 2020; Powers et al., 2015; Verma et al., 2015) of STEM programs. Explicit STEM youth programs that target the recruitment and continued support of diverse, historically underrepresented populations require continued and authentic EDI training for youth to meaningfully develop socially safe mentor-mentee relationships (e.g. Hennessy Elliott, 2020; Phelan et al., 2017; Renken et al., 2021). Several systematic reviews have been published on STEM program outcomes, such as best practices for practitioners (Anwar et al., 2019), subject-specific outcomes for robotics competitions (Dwivedi et al., 2021), youth learning outcomes (Davis et al., 2021), underrepresented STEM groups (Jin, 2021; Ozis et al., 2018).

Robotics leagues such as the non-profit organization For Inspiration and Recognition of Science and Technology (*FIRST*) incorporate competitive team project-based learning (PjBL) to design and build robots that collaborate in annual sports-style challenges (Yoel et al., 2020). *FIRST* Leagues are divided by youth age group *FIRST* LEGO League Challenge (FLL Challenge) (age 4-16), *FIRST* Tech Challenge (FTC) (ages 12-18), and *FIRST* Robotics Competition (FRC) (ages 14-18). While ages overlap, the complexity of engineering and programming challenges vary per league, in addition to team size and competition goals. Each *FIRST* team is guided by mentors, who serve as subject matter experts in a mentor-mentee relationship lasting 6-9 months each year.

The remainder of this chapter will illustrate a literature review relevant to its two major themes: volunteer mentorship and youth STEM programs. In section 2.2, I introduce the concept of volunteer mentorship and its prevalence in both Canada and the United States before discussing volunteerism in youth mentorship programs (2.2.1) for teachers (2.2.1.1), industry professionals (2.2.1.2), and near-peers (2.2.1.3). I also provide an overview of volunteers' motivation to mentor (2.2.2), as well as professional development opportunities for mentors (2.2.3), including the need for youth engagement training (2.3.3.1) and program-specific guidelines (2.2.3.2). Section 2.3 describes the prevalence of youth STEM programs, with a focus on competitive youth STEM programs (2.3.1), mentorship approaches for competitive STEM programs (2.3.2), and student outcomes for these programs in particular (2.3.2.1). Next, I will discuss the intersectionality of underrepresented populations in STEM programs (2.3.3), including socio-cultural factors (2.3.3.1), gender (2.3.3.2), and socioeconomic status (2.3.3.3). Following these discussions, I share limitations and gaps in the literature (2.4) that informed the research questions (2.5) and study design. Finally, I will provide an overview of the theoretical framework underpinning the study's design (2.6) and its conceptual framework (2.7).

2.2 Volunteer Mentorship

Across the mentorship literature, unless a program explicitly targets recruitment and support of underrepresented mentors or participants (e.g., Kim et al., 2021; Powers et al., 2015), there are limited examples of the diversity of personal mentorship backgrounds (e.g., Aresi et al., 2020; Hennessy Elliot, 2020; Miranda-Diaz et al., 2021; Teye & Peaslee, 2020), or mentorship demographics are not reported in depth (e.g., Cicchinelli et al., 2022; Dolenec et al., 2016; Franck & Donaldson, 2020; Kekelis et al., 2017;). Table 2.1 includes the most recent census reports in Canada (Hahmann, 2021) and the United States (AmeriCorps, 2023) for volunteers who contributed to activities such as youth mentorship, churches, sports, and non-profit programs.

In 2016, in the United States, approximately 15.65 million Americans donated their time to educational and youth program-related activities (Miranda-Diaz, 2021), which include raising funds, supporting field trips, classroom visits, and youth mentorship. Coaching in an educational setting ranges from sports teams to STEM clubs, to which 41% of Canadians (Hahmann, 2021) and 23% of Americans (Americorps, 2023) regularly volunteer annually. More narrowly, approximately 2.9 million Canadians volunteered formally with an organization as a formal mentor or coach in 2018 (Hahmann, 2021). Table 2.2 overviews Canadians' formal volunteer coaching or mentorship rates by age.

Table 2.1

Summary of 2018 Canadian & 2021 American Volunteer Censuses

Metric	Canada (2018)	United States (2021)
Sample size	16,149	127,872
% of population volunteers	41%	23%
# of population volunteers	12.67 million	60.70 million
Average annual hours of contribution per person	131	72
Gender		
Woman	44%	57%
Man	38%	43%
Did not respond	18%	0%
Generation		
iGen/Generation Z [Age 15-22]	14%	6%
Millennials [Age 23-37]	25%	26%
Generation X [Age 38-52]	25%	26%
Baby Boomers [Age 53-72]	28%	34%
Matures/Silent Generation [Age 73+]	8%	8%
Race		
American Indian or Alaskan Native	Not Collected	1%
Asian	Not Collected	3%
Black/African American	Not Collected	7%
Native Hawaiin/Pacific Islander	Not Collected	0%
White/Caucasian	Not Collected	87%
Two or more races	Not Collected	2%
Disability		
Disability	Not Collected	10%
No disability	Not Collected	90%
Annual Household Income		
> $150,000	Not Collected	22%
$100,000 - $149,999	Not Collected	19%
$75,000 - $99,999	Not Collected	15%
$50,000 - $74,999	Not Collected	18%
<50,000	Not Collected	20%

A broad body of literature on mentoring exists in three major areas, including youth mentoring, academic mentoring, and workplace mentoring (Dolenec et al., 2015), as described below:

- *Youth Mentoring:* must involve the youth as a mentee and primarily focuses on a mentor developing lasting relationships with the youth, which can improve the youth's positive identity and skills development.
- *Academic Mentoring:* must involve a student of any age as the mentee and improve a mentee's attitudes toward school, academic achievement, and the connection between academics and future careers.
- *Workplace Mentoring:* occurs in career or working environments to enhance a mentee's career development, satisfaction, and feelings of balancing work and other aspects of a mentee's life.

Mentorship programs for all types of mentorship can exist in 1:1 formats between a mentor and a mentee and varying combinations of mentors to mentees. Programs have various meeting times, formats, and frequencies agreed upon between mentors and mentees. Subject-specific mentorship programs in any mentorship category have varied subject matter. For example, the mentorship of a broad STEM club versus the specific mentorship of a single coding language. A mentorship program may also target broad or specific groups (e.g., a workplace mentorship program, women in STEM program, or a club for students in a given school district).

Table 2.2

2018 Canadian Volunteer Coach/Mentorship Rate by Age

Volunteer Age	Total Registered Volunteers	# Registered as Coach / Mentor	% Who Coaches / Mentors
iGen/Generation Z [Age 15-22]	1,773,000	247,951	10%
Millennials [Age 23-37]	3,139,000	777,198	10%
Generation X [Age 38-52]	3,162,000	788,629	10%
Baby Boomers [Age 53-72]	3,608,000	1,026,792	3%
Matures/Silent Generation [Age 73+]	996,000	78,247	1%
Total	**12,678,000**	**2,918,818**	**9%**

2.2.1 Youth Program Mentors

Youth mentorship programs provide opportunities outside the classroom to develop relationships in an informal learning environment (Davis et al., 2021). For youth mentorship programs, a minimum of 24 weeks of mentorship between a mentor and their mentee is required to develop positive growth in a youth program (Aresi et al., 2020). Length and meeting frequency of youth mentorship programs vary and can include the following:

- *Regular mentorship frequency, lasting less than 24 weeks:* These mentorship relationships often develop through short-term summer camps and drop-in spaces (e.g., Kim et al., 2021; Ozis et al., 2018; Powers et al., 2015).

- *Irregular mentorship frequency, lasting 24 weeks or more:* Mentors and mentees may meet regularly over a short period, followed by a period of low or irregular contact in a cyclical format. These programs often include specialized camps for youth and may be targeted towards a specific subject or group, where mentors and mentees participate annually (e.g., Aresi et al., 2020; Phelan et al., 2017; Wickliffe et al., 2020).
- *Regular mentorship frequency, lasting 24 weeks or more:* Youth programs meeting regularly with frequent participation from both mentors and mentees either in 1:1 or group mentorship formats (e.g., Dolenec et al., 2016; Hennessy Elliott, 2020; Kekelis et al., 2017; Koomen et al., 2021; Teye & Peaslee, 2019; Yoel et al., 2020).

In contrast to school environments, participants in youth mentorship programs describe their interactions as being social, intense, and close with peers and mentors (Verma et al., 2015). Regardless of meeting frequency and length, informal learning environments allow participants to build skills and form apprentice-like relationships that enhance the transfer of subject-specific knowledge (Witherspoon et al., 2018). Experiential activities such as hands-on projects, visits to job sites, and job shadowing opportunities are vital to youth mentorship programs. The literature recommends designing informal learning environments focused on learner-driven, low-stress relationship-building between youth and adult mentors (Aresi et al., 2020; Davis et al., 2021; Koomen et al., 2021).

Recruiting diverse mentors, including former participants and industry experts, is critical to strengthening the quality of youth mentorship programs (Wickliffe et al., 2020). Regardless of mentorship type and youth program location, a close relationship between a mentor and mentee can be achieved (Aresi et al., 2020). Mentor identities are intersectional, where a mentor may represent multiple social backgrounds simultaneously. An industry mentor may also be close in age to the youth program that they are serving (identifying as a near-peer mentor). These identities may shift as a near-peer mentor grows older (identifying as an industry mentor), or an education mentor may transition careers (identifying as an industry mentor). The distinction between industry mentors and teacher mentors has been made due to the high prevalence of educators organizing or participating in youth programs.

Additionally, teacher mentors must have some working knowledge of conflict resolution and classroom facilitation (2.2.1.1), whether pre-K-12 or post-secondary. Parents who serve explicitly as mentors to a youth program are identified in the literature among industry mentors who provide specialized experience through their mentorship. Though essential to the development and support of youth programs, financial sponsors, parents supporting their children at home, and the greater community are not included as types of mentors.

2.2.1.1 Teachers as Mentors

Due to increased access to youth communities as part of their careers, many educators serve as mentors to youth programs. A review of 150 publications on subject-specific youth mentorship programs found that clubs commonly draw on one to two teachers to operationalize a program for youth (Davis et al., 2021). Teacher mentors may be exposed to other relevant training that supports managing youth programs in a group setting. These educators frequently manage youth programs in addition to their day-to-day duties, including 50-150 hours of unpaid organizational time per STEM competition a team registers in (Fisanick, 2010). These administrative educators often serve as “Lead Mentors” (FIRST, n.d.), whose additional administrative duties include maintaining annual registration fees, booking competitions, and inviting all students and mentors to participate in a given team. Aside from mentorship of students in a youth program, Lead Mentors must also be focused on strategically recruiting support from their larger community. Professionally, 52% of Lead Mentors serve as educators full-time, with an average of 6.5 mentors supporting a single team (Center for Youth and Communities, 2011). In one example of a STEM program primarily serving Indigenous students in a rural community, the Lead Mentor carefully rotated their work with students every few years so as not to “over tax” their support network of professors, program alumni, and the Tribal College (Koomen et al., 2021).

2.2.1.2 Industry Professionals as Mentors

The terms “industry,” “professional,” and “corporate” mentors have been used interchangeably in the literature to refer to a working professional serving as a youth program mentor who is not in the education industry. The presence of industry professionals to serve as content experts and trainers for fellow mentors is critical for specialized topics of youth programs such as STEM clubs or sports competitions

(Dwivedi et al., 2021). Industry mentors may be recruited in a variety of ways, including subject-specific societies and alliances (Jin, 2021), higher education (Powers et al., 2015), and local cultural centres (Koomen, 2021). For youth programs affiliated with K-12 institutions, the need for more professional development programs for up-to-date subject knowledge can result in them relying on local professionals to mentor their programs (Ozis et al., 2018). Notably, the support of professional volunteers as mentors can increase the success of implementing technical programs due to their background in relevant and up-to-date subject matter (Franck & Donaldson, 2020).

2.2.1.3 Near-Peers as Mentors

Unlike an industry expert or teacher who is an experienced mentor to youth programs, a near-peer may be a similar age or a few years older than a mentee. The closeness in age can allow for a mentor-mentee relationship to build higher degrees of trust and informality, with near-peer mentors possessing a higher understanding of unspoken norms and expectations, relevant content-specific and program knowledge compared to industry or education mentors (Kim et al., 2021). Across the literature, near-peer mentorship has also been referred to as “graduate mentor” (e.g., Yoel et al., 2020), “cross-generational mentorship” (e.g., Koomen et al., 2021), “senior mentors” (e.g., Wickliffe et al., 2020), or “peer teachers” (e.g., Davis et al., 2021). Due to the frequency of the term “near-peer” across the reviewed publications, to ease confusion, all examples of mentorship will be classified as “near-peer,” with explicit reference if the peer is also a graduate or alumni from the program which they mentor.

Research has shown that near-peer relationships in informal youth mentorship programs positively impact academic achievement after high school (Zaniewski & Reinholz, 2016). Organizations with several youth programs spanning K-12 may use active program participants as near-peer mentors for younger groups. For example, in a Native American youth program for middle-school students, recent program graduates would return annually to demonstrate their work and describe their current experiences in the high-school youth program (Koomen et al., 2021). The active recruitment of near-peer mentors also has a documented increase in youth program sustainability (e.g., Davis et al., 2021; Wickliffe et al., 2020), as active participants view mentorship as the natural next step after aging out of a community program. Near-peer mentors also increase experienced participants' willingness to teach newer members about program-specific topics, thus strengthening collaboration between participants in a club. (Verma et al., 2021).

Near-peer mentors are notably impactful for the growth and participation of underrepresented backgrounds. Programs serving specific underrepresented youth have successfully increased program sustainability by directly recruiting recent program graduates as near-peer mentors (e.g., Koomen et al., 2021; Phelan et al., 2017). The ability of near-peer mentors to discuss struggles and lived experiences can build self-efficacy in program topics and develop confidence in a mentee (Kim et al., 2016). A description of the impact that mentorship of STEM programs, including near-peer mentors, has on youth participants of diverse backgrounds is in section 2.3.3.

2.2.2 Mentor Motivations

Volunteers' motivation varies per person and influences the chosen volunteer organization or topic to which they donate their time. Across the literature, volunteers are motivated to give time to develop personal skills, build career growth, and assist in growing their community (Cicchinelli & Pammer-Schindler, 2022; Miranda-Diaz et al., 2021). A volunteer's identity and background have been found to influence mentorship skills, applications, and motivations. Women and mentors of colour are more likely than other genders and cultural backgrounds to seek mentorship opportunities that allow for growth in their personal lives or careers (Miranda-Diaz et al., 2021). Similarly, the influences of the age of a mentor consistently demonstrate that volunteers in their early twenties are motivated by opportunities supporting personal career growth compared to older volunteers (e.g., Hahmann, 2021; Miranda-Diaz et al., 2021; Teye & Peaselee, 2020).

As volunteers develop life skills, their motivation to mentor begins to shift. In Canada, 25% of volunteers aged 22 and older are motivated by volunteer opportunities that contribute to the well-being of their community (Hahmann, 2021). Regarding youth mentorship programs, Teye and Peaslee (2020) described mentors as highly motivated first by a desire to make the world a better place, followed by the desire to gain a greater understanding of the world and its diverse people. Recent graduates who return to a program as a near-peer mentor are often motivated to continue supporting a program that impacted them as a child (Yoel et al., 2020). Further, mentors motivated by altruism may be well-suited to developing relationships with underrepresented youth, as explored for youth STEM programs in section 2.3.3. Though mentors may be individually motivated to “make the world a better place,” youth mentorship programs often develop a culture where experienced mentors and mentees teach new members as they learn (Dolenec et al., 2016).

Mentors' satisfaction with their work and closeness in relationships between mentees and fellow mentors significantly influence their intentions to continue volunteering in a youth program (Aresi et al., 2020). Factors such as the structure of activities, available support of mentorship from fellow mentors, and the youth program’s meeting length and frequency also influence the recruitment and retention of mentors (McMorris et al., 2018). Youth programs that provide training, guidance, and feedback for mentors outside of youth meeting times have increased mentor satisfaction and retention (Aresi et al., 2020). Across the literature, researchers suggest a Lead Mentor or administrative figure support the placement and professional development (2.2.3) of newer mentors (e.g., Franck & Donaldson, 2020; Kekelis et al., 2017; Powers et al., 2015; Teye & Peaslee, 2020). Asking mentors energized by social gatherings to manage an upcoming community event will result in more profound mentor-mentee relationship growth and higher mentor-individual satisfaction.

2.2.3 Professional Development for Mentors

New mentors require relevant program content knowledge to support youth programs effectively. Professional development and mentorship training programs should be flexible to reflect the varying strengths of teacher, industry, and near-peer mentors.

Across the literature, recommendations for mentorship training and engagement per group have been described.

- *Teacher Mentors:* Have increased rates of serving as a youth program's Lead Mentor (2.2.1.1), where they train and recruit new mentors from the community (Center for Youth and Communities, 2011; Koomen et al., 2021). While they possess youth facilitation skills at a higher rate, they have lower subject-specific knowledge (Dwivedi et al., 2021).
- *Industry Mentors:* Require support in engaging youth, group facilitation techniques, and youth engagement training (2.3.3.2), including age-appropriate teaching methods (Jin, 2021; Franck & Donaldson, 2020). Industry mentors are strong at growing opportunities for hands-on learning, such as internships and site visits for youth mentorship programs (Koomen et al., 2021).
- *Near-Peer Mentors:* Demonstrate higher expectations towards the growth of mentor-mentee relationship quality (McMorris et al., 2018). Continued feedback between experienced mentors and newer near-peer mentors may support the retention of this group.

Mentor training programs increase mentor satisfaction and retention (Aresi et al., 2020) and make learning to mentor less overwhelming for newer mentors (Franck & Donaldson, 2020). Continued feedback on mentorship tactics, program expectations, and subject-specific knowledge is essential for retaining all mentors (Powers et al., 2015).

Though essential to the sustainability of youth mentorship programs, a Lead Mentor or administrator's role in developing mentorship training and practices requires extensive time and energy.

Recommendations for hiring dedicated administrative (or Lead) mentors (Kekelis et al., 2017; Powers et al., 2015) support developing high-quality youth programs with consistent mentorship guidance. In many cases, youth mentorship programs may often lack financial, administrative, or institutional support that facilitates hiring dedicated staff (e.g., Aresi et al., 2020; Dwivedi et al., 2021). Using existing online training programs (Davis et al., 2021), mentors can receive professional guidance and build an understanding of the greater program community. Youth STEM programs feature a variety of training opportunities for mentors, including the *FIRST* Mentor Network, mentor and Lead Mentor guides, Equity, Diversity, and Inclusion Mentor Certificates, and Professional Development Programs (FIRST, 2021a). Informal training opportunities also exist in online forums on social media platforms, and 1:1 mentorship opportunities between a Lead Mentor and a newly recruited mentor to a team.

2.2.3.1 Youth Engagement Training

As a vulnerable population, the safe and respectful relationship between youth and adult mentors is critical to a program's continued operation. Participation in training modules about mentor-mentee relationship development, group facilitation techniques, and authentic EDI training is critical for all mentors, regardless of previous experience (Kekelis et al., 2017). For example, for mentors supporting youth who have a disability, some mentors “hardly ever discussed disability because [they] kind of felt awkward” (Powers et al., 2015, p. 35). Regardless of a mentor or mentee’s background, youth mentorship programs which provide mentor EDI training and continual support are essential to a successful mentor relationship (Powers et al., 2015), which may reduce instances of feeling awkward or uncomfortable when engaging in authentic EDI conversations, such as disabilities.

Mentorship training topics such as youth engagement and presentation tactics are also crucial for volunteers new to youth mentorship programs (Franck & Donaldson, 2020; Jin, 2021). By sharing exemplary mentorship stories, new mentors can learn about program expectations and practice mentorship informally in their existing network before their youth mentorship contributions begin (Kekelis et al., 2017). Mentors who build confidence in their mentorship practice are better equipped to support mentee growth. Kekelis et al. (2017) describe exemplary mentorship in this way:

> [The mentor] became deeply engaged as a partner in the project without being “the adult” who made the final decisions. This stance was demonstrated when [the student] and [the mentor] started to speak at the same time, but [the mentor] insisted that [the student] go first. This subtle move shifted power from the adult in the room to the girls. [The mentor] gave the group the space to pursue their own ideas and solve their own problems, providing support but not instructions (p. 13).

For mentors supporting youth programs outside their subject knowledge and personal background, direct training is required to increase confidence in mentor-mentee interactions and demonstrate empathy. A mentor’s ability to connect with mentees on interests outside of subject-specific topics increases mentor satisfaction and program retention (Cicchinelli & Pammer-Schindler, 2022). For example, mentorship training should emphasize developing opportunities for informal interaction on personal and career interests (Powers et al., 2015).

2.2.3.2 Program-Specific Training

While industry mentors in programs such as 4-H STEM provide valuable subject-matter expertise, mentors often require additional training and mentorship to translate technical subject knowledge to be accessible to youth audiences (Kekelis et al., 2017). Program-specific practices, terms, and language often result in onboarding processes per program, regardless of a mentor's relevant professional knowledge. As a starting point, youth mentorship programs using building kits or templates can lean on equipment suppliers' instructions (Dwivedi et al., 2019).

Though subject matter experts such as industry mentors provide a depth of knowledge, they require support in identifying curriculum links and age-appropriate concepts (Jin, 2021). Short, hands-on training opportunities to increase mentor retention are more effective than general mentor recruitment tactics such as advertising and small monetary incentives (Franck & Donaldson, 2020). In creative and physical projects, hands-on training for mentors to build a project before beginning to mentor students can bolster mentor confidence, provide firsthand problem-solving experience, and model program expectations for new mentors (Kekelis et al., 2017).

2.3 Youth STEM Programs

A community surrounds STEM programs that help facilitate students' participation and growth in the subject matter. Like volunteer mentorship generally (2.2), STEM supporters include administrators, teachers, industry professionals, program alumni, and parents. For STEM programs for older children and teens, such as grades 9-12 robotics, several studies recommend that mentors take a facilitator approach by encouraging students to build their projects (Davis et al., 2021; Dolenec et al., 2016; Kennedy et al., 2016). For example, industry mentors may teach students how to operate machinery safely on a competitive robotics team. However, students remain responsible for all design decisions and the production of the group's robot.

Additionally, parents, participants, and mentors overwhelmingly agree that an essential aspect of STEM programs for youth is the opportunity for experiential activities jointly shared by youth and mentors (Powers et al., 2015). These experiential activities in STEM programs focus on increasing youth confidence and understanding of further STEM opportunities. Activities may include shadowing professionals at job sites, visiting colleges, and relationship-building activities not solely focused on STEM.

2.3.1 Competitive STEM Programs

While language across the literature varies, within competitive robotics communities such as *FIRST*, mentors and youth participants define their experience as contributing to a competitive robotics team. The use of the word "team" emphasizes the relationship to school athletic programs, contrary to administrators' or non-participants' use of the word “club” (Hennessy Elliott, 2020). As a team, students and mentors in competitive STEM programs meet in a format they choose, often similar to sessional projects. However, the group works towards the culminating task surrounded by competition within the larger STEM community. A robotics challenge may have different competitive prompts each year, such as balancing a robot on a teeter-totter, picking up a ball and placing it in a goal within a time limit (Yoel et al., 2020). For consistency of learning outcomes and logistics, the robot's size, permitted building materials, and playing size of the competition field are broadly consistent yearly.

Several studies link the participation of competitive robotics teams as examples of communities of practice (e.g., Davis et al., 2021; Hennessy Elliott, 2020; Koomen et al., 2021; Verma, 2015;). Communities of practice are groups of people who share a common interest in a domain or subject area and practice those interests as a community over time. These communities of practice have been defined in the scope of the larger *FIRST* community and on a team-by-team scale for each competitive team’s robot. In contrast to a non-competitive robotics team, students on competitive teams such as FRC demonstrate their integration into a community of practice through acts of authentication in resource-rich environments (a robotics competition) between novice (a student) and knowledgeable (a mentor) members of the *FIRST* community (Verma, 2015). The use of technical language associated with a robotics competition demonstrates a student’s integration into their community of practice. As further described by Verma (2015), these acts of authentication in the larger community of practice are demonstrated by students' ability to utilize language during a competition to address engineering challenges such as traction, ranking points, and center of mass. At an individual team scale, mentors and students may have special terms associated with maintaining their robots and processes for evaluating other teams' competitive success, thus forming a smaller community of practice within the FRC community (Hennessy Elliott, 2020).

2.3.2 Competitive Youth Mentorship Approaches

In educational psychology, sports, and competitive robotics, a focus on a step-by-step approach, experimentation opportunities, and well-trained coaches are critical to the team's success. (Dwivedi et al., 2021). Primarily, *FIRST* mentors are concerned about the availability of mentor resources and how to navigate student inequities, including finances and gender (Center for Youth and Communities, 2011). In competitive STEM programs, a team's mentorship approach influences student outcomes and the team's competitive success. *FIRST* mentors have described that while challenging, their approach to mentorship is to create an environment where students are supported in designing and building their robot in response to the annual competition prompt instead of being instructed on what and how to make it (Dolenec et al., 2016). Additionally, robotics programs prioritizing student participation over competitive success have more equitable participation of underrepresented students on their teams (Witherspoon et al., 2018). Mentors must be careful to continually prioritize mentorship practices over the competitive success as a team so as not to disproportionately affect the engagement of minority groups in STEM, such as young women (2.3.3.2).

During the competition season, additional challenges, such as students' ability to manage their time effectively and concerns about the teams' competitive success, can result in mentors overstepping their communicated boundaries. Examples of mentor boundary shifting due to prioritizing competitive success may include mentors performing student tasks such as machining parts and overriding engineering design choices, thus reducing student agency and ownership of their project (Dolenec et al., 2016). Changing mentorship practices may also result in confusion, team cohesion challenges, and a lack of student integration into their community of practice. While this trend is present in both sessional and competitive STEM programs, for competitive programs primarily, using the non-competitive time to build mentorship and new member experience in addition to general mentorship training (2.2.3) may support the commitment to the team throughout the higher-stress competition season. For example, a recent study of *FIRST* teams at a regional competition found that of the teams which advanced competitively or were recognized with awards, 85% of them engaged in off-season training for both students and mentors (Dwivedi et al., 2021).

Outside team meeting spaces, program developers carefully plan the location of robotics competitions. In Ontario, 77% of FRC events in the 2022-2023 season were hosted at university or college venues (FIRST, 2023). The unique opportunity to introduce students, mentors, and the STEM community to post-secondary opportunities provides students with a sense of college and university atmospheres and experiences for diverse populations of students (Wickliffe et al., 2020). Exposure to additional community spaces may serve as informal field trips, providing students with opportunities to connect to other communities of practice in informal learning environments.

2.3.2.1 Student Outcomes in STEM Programs

The mentor or educator's attitude significantly impacts student participants' learning outcomes in STEM programs. For example, team members with low self-efficacy have lower grades in school, which can be positively changed with team members or mentor guidance (Yoel et al., 2020). Out-of-classroom experiences with hands-on learning opportunities allow students to engage in STEM topics meaningfully. Indeed, studies show that students connect meaningfully with informal learning experiences associated with hands-on mentorship (Verma, 2015), such as robotics teams. While participation in STEM programs, both non-competitive (e.g., Maker Camps, BASE Camp) and competitive (e.g., *FIRST,* VEX), provides students with global competencies, workplace skills and academic self-concept (Meschede et al., 2022), there is no statistically significant difference in this skill attainment of these skills in comparison to other community-based informal learning programs such as 4-H and Scouts, sports and musical theatre activities (Burack et al., 2019).

Several studies document that students participating in STEM programs are more likely to develop an interest in STEM disciplines after high school (e.g., Anwar et al., 2019; Burack et al., 2019; Meschede et al., 2022; Whitherspoon et al., 2018). Though youth who initially enroll in a STEM club may have a higher STEM perception than those who choose never to join, their continued participation in STEM clubs significantly increases their STEM perceptions and the likelihood of pursuing STEM programs after high school (Ozis et al., 2018). A 96-month follow-up of *FIRST* participants continues to find that *FIRST* programs positively and statistically significantly impacted STEM interests relative to the comparison group (Meschede et al., 2022). Specialized STEM competitions focusing on the depth of STEM knowledge in targeted STEM subjects, such as engineering, increase STEM perceptions more than a breadth of STEM topics (Ozis et al., 2018). For example, *FIRST* alumni are significantly more likely to show interest in engineering (2.3 times) and computer science (1.8 times) topics in post-secondary but slightly less likely to demonstrate an interest in biology (.3 times) and health sciences (.35 times) (Burack et al., 2019). Through interviews with *FIRST* alumni about the influence of their participation, Yoel et al. (2020) also found that *FIRST* alumni have significant exposure to technology and computer science topics through competitions. At the same time, they may lack confidence in pursuing topics such as biology in post-secondary, regardless of gender (Yoel et al., 2020).

2.3.3 Intersectionality in STEM Programs

Representing minority populations by students and mentors has an essential impact on the participation of similar underrepresented groups engaging in a STEM program. Intersectionality refers to how multiple forms of social identity (race, gender, class, disability) intersect to influence a person's lived experience rather than the independent impacts of a single social identity (Renken et al., 2021). Demographically, for the mentorship of youth STEM programs specifically, there is an overrepresentation of mentors in their forties who identify as Caucasian men (Center for Youth and

Communities, 2011; Hennessy Elliott, 2020; Verma et al., 2015; Powers et al., 2015). As described in section 2.3.2.1, the representation of mentorship on competitive teams like FRC can lead to similar participant populations. Though the overrepresentation of men who volunteer in STEM programs contrasts with descriptions of youth mentor demographic trends described above (2.2.1), strategies and mentorship practices align with that of youth STEM programs. Mentors may exhibit ethnocultural empathy by demonstrating acceptance of cultural differences and empathetic awareness. A mentor's ability and willingness to share personal stories, struggles, and successes can especially increase self-beliefs for students of colour (Kim et al., 2021). Though age, race, and ethnicity are not statistically significant predictors for ethnocultural empathy, women who mentor are more likely to exhibit higher levels than men (Miranda-Diaz et al., 2021). Similarly, mentors with disabilities have an increased ability to support mentee self-efficacy due to a heightened ability to validate and support disability-related barriers in STEM career success (Powers et al., 2015;). Regardless of personal experience with navigating barriers in STEM, authentic EDI training (as described in 2.3.1.1) is essential to supporting a mentor's ability to build a trusting relationship between a mentor and mentee.

STEM program mentors who identify as one or more underrepresented groups, such as young professionals, mentors with disabilities, and ethnic minorities, serve as excellent near-peer mentors for youth in STEM programs (e.g., Kekelis et al., 2017; Phelan et al., 2017; Powers et al., 2015). Younger mentors may serve as near-peer mentors (2.2.1.2) to STEM program participants, sharing recent experiences with post-secondary education topics and early career development outside the STEM program (Kekelis et al., 2017). Indeed, FRC alumni and researcher Hennessy Elliott illustrates the journey of a woman Latinx *FIRST* participant as a "resistance to the local and larger histories of *FIRST* robotics team practice(s)" (2020, p. 633). Hennessy Elliot describes the student's time on the team,

> positioned by her peers as a controlled driver who has little to no decision-making power in what the robot does or how it should accomplish the tasks at hand in competition matches. Here, her learning is actively set aside so she can listen and perform as she is told by another member of the team. The goal of winning the competition is privileged over furthering [her] development. (p. 628)

While the participant's identity as a Latinx woman on the robotics team is described, the impact of the dangers of prioritizing competitive success over student outcomes is made clear (as described in section 2.3.2.1). Multi-faceted and intersecting identities make it challenging to have entirely different narrations of underrepresented participants and mentors in STEM programs. While in reality, the mentorship of youth STEM Programs serves a range of intersecting identities, some literature highlights common demographic themes and implications for both mentors and participants.

2.3.3.1 Socio-Cultural Factors

The representation of adults and peers from similar cultural backgrounds or ethnicities has documented impact on student self-efficacy and academic achievement (e.g., Hennessy Elliott, 2020; Howard & Reynolds, 2008; Jin, 2021; Kim et al., 2021; Koomen et al., 2021; McGee et al., 2015; Phelan et al., 2017; Powers et al., 2015; Wickliffe et al., 2017). Students of colour who have the opportunity to build meaningful relationships with same-race mentors and educators can build help-seeking behaviours that lead to deeper learning (Kim et al., 2021). Each culture has unique relationships between educators and students and their relationship to learning. In many Indigenous cultures, the teacher or mentor guides a student to take ownership of learning (Koomen et al., 2021). While Indigenous students may have access to fewer STEM programs to participate in, school-based mentoring and informal learning environments can increase STEM beliefs for this population (Koomen et al., 2021).

The presence of ethnocultural empathy in mentors can support a youth mentee's identity exploration (Peifer et al., 2016). Though primarily a Caucasian sample, mentors surveyed by Powers and colleagues (2015) demonstrated ethnocultural empathy through their findings of 1:1 mentorship programs. For program mentors, a mentor's ability to have meaningful conversations about relationship building with mentees from other ethnicities was equally motivating as same-race and same-ethnicity matches, as long as 1:1 matches shared other common subject interests (Powers et al., 2015). Similar to trends in Canadian and US volunteerism (2.2), mentors of competitive robotics teams are 82-85% Caucasian (Center for Youth and Communities, 2011).

Outside of mentorship alone, parental support is a significant contributor to student participation in STEM programs (e.g., Davis et al., 2021; McMorris et al., 2018; Powers et al., 2015; Yoel et al., 2020) for minority populations such as African American students, girls, and low-income families especially (e.g., McGee et al., 2015; Phelan et al., 2017). Sixty-four percent of FRC alumni indicated that their family provided a supportive environment to participate in robotics competitions (Yoel et al., 2020). Parents exhibit cultural differences in supporting their children's engagement in STEM topics. Two studies suggest that African-American parents are more likely to demonstrate support for youth programs through relationship-building with their children in home-based projects (Howard & Reynolds, 2008; McGee & Spencer, 2015). Mentors must continually build strong relationships within the greater community, including building trust through informal communication with family members, providing open house opportunities, and allowing families to see that no harm will come to their children (Koomen et al., 2021).

2.3.3.2 Gender

While gender expression is not exclusively limited to those who identify as men and women, STEM programs such as *FIRST* and resulting technical industries are statistically dominated by men (Burack et al., 2019). The literature surrounding gender topics in STEM programs documents the need to increase women's representation and participation in STEM. However, there is little documentation of gender-diverse perspectives, such as transgender and non-binary participants in STEM programs. For competitive robotics teams, men may be societally more competitively motivated than women (Witherspoon et al., 2018), which may disproportionally increase the participation of men in highly competitive or complex programs. Men may also feel disproportionately pressured by their peers to join competitive STEM teams and pursue technical career interests.

In contrast to general volunteerism demographics for Canada and the US (2.2), studies of mentor distribution among competitive robotics programs such as VEX found that while middle school teams had an equal number of men and women volunteers, the more technical high school group had fewer than 27% of mentors who are women, and do not report any genderfluid, non-binary, or transgender mentors (Hendricks et al., 2012). Similarly, 21-26% of registered mentors for FRC and FTC team mentors are women (Center for Youth and Communities, 2011). Active recruitment of women mentors and mentees increases the likelihood that more women will join a competitive STEM program (Yoel et al., 2020). To retain women, non-binary, and genderfluid participants, men on a *FIRST* team are responsible for co-constructing an environment of inclusivity and opportunity. The inability to create an inclusive space for learning can result in girls leaving a *FIRST* team or hesitating to participate in areas where they might have initially shown interest, such as programming and building the robot (Hennessy Elliott, 2020).

While *FIRST* alumni have an increased interest in computer science topics in post-secondary, it is crucial to note the dynamics between minority populations on *FIRST* teams and in published research. Interviews with *FIRST* alumni reveal that past participants see *FIRST* teams as a safe space where girls can feel capable of executing mechanical and computer science-based tasks. (Yoel et al., 2020). Whitherspoon et al. 's (2018) review of five competitive robotics programs, the older and more complex the programming challenges became, the more significant the gender divide for student participants. While significant, the gender gap in complex, competitive STEM programs, such as the *FIRST* Robotics Competition, shares a 5:1 man-to-woman ratio similar to that of Advanced Placement (AP) computer science and post-secondary engineering courses (Whitherspoon et al., 2018). AP courses are offered to academically advanced high school students and provide an opportunity to receive college or university credit for specialized courses completed while enrolled as a high school student.

2.3.3.3 Socioeconomic Status

The socioeconomic status of students, as well as an overall region serving a competitive STEM team, can have an impact on program implementation. Socioeconomic status (SES) is determined by a combination of an individual or group's income, level of education, location of residence, and type of employment (Ado, 2019). Similarly to mentors serving as youth volunteers for non-STEM programs (2.2), most STEM program mentors in available literature have at least a bachelor's degree, with a household income above $50,000 annually, and are employed full-time. (Miranda-Diaz et al., 2021). Rural and remote communities may face lower SES conditions and less funding access than other regions. (Koomen et al., 2021). In a review of several competitive robotics programs, registration fees and the cost of building materials remain a vital equity concern for the equitable implementation of STEM programs (Dwivedi et al., 2021). Informal learning opportunities outside of school are especially vital for low SES communities, whose underfunded science curricula and limited access to STEM mentors significantly reduce student self-efficacy (Phelan et al., 2017). Successful STEM programs include team and individual scholarships for underrepresented groups, which depend on annual grants and corporate donations (Koomen et al., 2021; Wickliffe et al., 2020).

2.4 Limitations & Gaps in Previous Research

Though the body of literature reviewed in Sections 2.2 and 2.3 represents an overview of the work in volunteerism and STEM programs, several limitations and gaps have informed the design of this thesis. While resources and support systems are available for learning about STEM programs, they are primarily practitioner reports. Peer-reviewed publications have analyzed these reports in depth in literature and systematic reviews, finding that there is a strong focus on the efficacy of programs, short-term outcomes for graduating participants, and curriculum development opportunities (Davis et al., 2021; Verma et al., 2015). Additionally, peer-reviewed studies recommend collecting multiple sources of data, such as interviews and focus groups, artifact collection, and survey data (Aresi et al., 2020; Kim et al., 2021; Koomen et al., 2021; Powers et al., 2015; Ozis et al., 2018).

As noted by Cicchinelli & Pammer-Schindler (2022), there is a significant gap in the understanding of the motivations of mentors to volunteer, as publications and literature reviews are primarily focused on the operational perspective of institutions that attract, train, and retain volunteers to youth programs. Though studies such as Aresi et al.'s (2020) and Kim et al.'s (2021) investigation of mentor motivations provides an understanding of the impacts of motivations on the quality of 1:1 mentorship, there are even fewer examples of how mentors support youth in a small group setting. A significant gap exists in investigating nuances in relationship development in small group settings and for mentors who identify as teacher mentors, industry mentors, or program graduates. Koomen et al. (2021) note a deficit in publications with an equitable lens that investigates the teacher's role towards competitive STEM programs for youth in a volunteer setting, particularly for Indigenous and rural STEM programs. Notably, studies investigating mentor motivations have also been limited by when the mentorship relationship data is collected, where mentors were interviewed before being matched with youth (Miranda-Diaz et al., 2021). An opportunity to connect with mentors during and immediately concluding their mentorship experience with youth will further research understanding of mentor's attitudes and beliefs when working with vulnerable populations.

Historic underrepresentation and inequities in STEM fields have resulted in a limited understanding of how diverse individuals are motivated and approach mentorship (Kim et al., 2021). In multiple studies, homogenous mentor sample populations limited the ability to analyze and extrapolate findings more broadly (Aresi et al., 2020; Miranda-Diaz et al., 2021; Powers et al., 2015). For example, Aresi et al. call for investigating the researcher's understanding of a mentor's age on mentor retention and relationship development, particularly for mentors younger than 50. Though studies have been conducted on mentorship approaches for youth and mentors with disabilities, sample sizes and demographic diversity are limited to primarily Caucasian youth with mostly invisible disabilities, which did not investigate influences on other identity factors such as sexual and gender identity, academic achievement, and income factors (Powers et al., 2015). While several studies investigate the influence of single identities in STEM youth mentorship, such as women in STEM, there are fewer investigations of how multiple and intersectional identities, such as women of colour in STEM, impact the development of mentor relationships (Kim et al., 2021). Though present, studies investigating the impact of multiple or intersectional identities in STEM are frequently illustrative, following a single individual or team (e.g. Dolenec et al., 2015; Hennessy Elliott, 2020). Researchers such as Powers et al., 2015 note that further research is "essential for understanding how mentoring can be effectively structured and supported to facilitate youth with […] intersectional statuses to successfully progress toward their STEM career goals" (Powers et al., 2015, p. 37).

Studies such as those conducted by Ozis et al. (2018) provide a foundational understanding of the nuances in operations and student outcomes between a breadth of competitive STEM programs (such as *FIRST*, BEST, VEX, and Science Olympiad), leaving an opportunity to investigate a single program's mentorship in depth. More narrowly, researchers have called to address the deficit of robotics competition literature, which may also inform the OST STEM education and understanding of self-directed learning (Dolenec et al., 2015). Notably, there are several studies linking *FIRST* teams and mentorship outcomes through Project Based Learning (PjBL) and the impact of the *FIRST* program on participants and graduates (Burack et al., 2019; Meschede et al., 2021; Yoel et al., 2020). While these studies expanded the understanding of the importance of mentors and volunteers for students, they focus on the mentee experience as research participants rather than collecting artifacts and stories from mentors. Significant opportunity exists to explore the diversity in mentorship approaches and program challenges with a single program such as *FIRST*. There are several calls for research on *FIRST* program mentorship, including the investigation of the influence of mentors on *FIRST* participants (Yoel et al., 2020), additional explorations of how youth from marginalized communities remake STEM spaces to be more supportive and equitable (Hennessy Elliott, 2020), and the relationship between competitive success and the mentorship of diverse mentee populations (Dolenec et al., 2015; Witherspoon et al., 2018).

2.5 Research Questions

To explore these gaps in the literature and understand how mentors approach STEM education for underrepresented populations, I designed the following research questions:

1. How have individual participants' mentorship approaches of grade 9-12 robotics teams evolved throughout their time as mentors?

2. What approaches do mentors use to develop a sense of community, particularly for underrepresented populations participating in grades 9-12 competitive robotics teams?

2.6 Theoretical Framework

To guide the research and support the data analysis, I employed a conceptual framework including three theories. "A theory is a statement, suggestion or proposition that brings together concepts and constructs into a coherent whole, framework or system which has clearly set limits and assumptions" (Cohen et al., 2018, p. 68). Theory drives the lens by which the researcher views the data within a study. The function of these three theories was to inform the research problem, approach, and analysis as it related specifically to the FRC program. Each theory is described in the sections below, followed by the conceptual framework, highlighting how the theories formed an interconnected structure that served as the study's guide.

2.6.1 Constructionism

Historically, learning has been perceived as a process where a teacher serves as an instructor, providing information in the form of lectures that students are expected to understand in the format presented. Constructionism is a theoretical framework and approach to pedagogy that supports student-centred learning, emphasizing discovery-based problems, where students connect new information and existing knowledge (Alimisis et al., 2009; Anwar et al., 2019). The theory of constructionism was developed through the use of educational robotics within the Massachusetts Institute of Technology (MIT) Media Lab, founded in the early 1980s (Anwar et al., 2019; Alimisis et al., 2009; Penska et al., 2017). The Media Lab's mission was to "forge a new science of expressive media driven by computational technology" (Psenka et al., 2018, p. 9).

In its simplest form, constructionism is rooted in "learning by making" (Papert & Harel, 1991). Inspired by the work of Jean Piaget's theory of constructivism, Seymour Papert believed that the use of technology to construct artifacts allowed students to construct their understanding of abstract concepts and curriculum (Papert, 1980; Psenka et al., 2017). Constructionism follows the constructivist paradigm that knowledge is built spontaneously but adds that producing a visual and public artifact makes ideas concrete for sharing and reflection (Papert & Harel, 1991; Psenska et al., 2017), where constructionism deviates from constructivism in its conceptualization of knowledge development over time. In constructivism, knowledge becomes more stable over time, whereas constructionism identifies how knowledge is continually constructed and rebuilt (Alimisis, 2012; Kynigos, 2015). Critical to constructionism is sharing, where learners can encourage collaboration and idea sampling, deepening learning while challenging traditional top-down characteristics of technical subjects (Kafai & Burke, 2013).

Researchers and practitioners have explored constructivist frameworks in education to address the interaction process among individuals and understand the specific context in which people live and work (Creswell, 2013). As an educational philosophy, constructionism directly contrasts with “instructionism.” Papert and Harel describe instructional learning modes as a passive knowledge transfer, often occurring in more formal or impersonal mediums such as textbooks or lectures (1991). Instructionist environments can reinforce the power dynamic of an educator as the source of expert knowledge, which may inhibit students’ natural curiosity and engagement on a given topic. Computers and other technology in a learning environment allow students to shift the balance between transferring and producing knowledge to students (Papert & Harel, 1991).

Teachers in a constructionist classroom act as facilitators and mentors to students, raising questions for learners to engage with over extended periods and encouraging creative problem-solving (Almisis, 2012; Noss & Clayson, 2015; Psenka et al., 2017). Students are encouraged to engage with problems “with gusto” (Papert & Harel, 1991, p. 9), developing a deeply personal and meaningful connection with their constructed artifact. Constructionist environments are playful, with a low-stakes and relaxed environment designed to de-emphasize the grading and evaluation of a produced artifact while allowing flexibility for multiple learning paths to construct their learning (Kynigos, 2015; Psenka et al., 2017). For example, Papert and Harel (1991) identify that in the production of a programmed spaceship, some learners approach the construction of their artifact more formally (as if following step-by-step instructions), while others prefer to approach the problem more abstractly (as if painting a picture). Critical to constructionist learning is the emphasis of educators supporting, rather than interrupting or interfering with, the learning process. Technical subjects common to STEM are biased towards top-down, formal learning styles, creating a gap in interest and authentic engagement for abstract learners (Resnick & Silverman, 2005). STEM programs framed with constructionist frameworks can allow more diverse learners to engage with abstract problems, thus strengthening the STEM pipeline.

Papert developed the programming language “Logo,” which used cutting-edge technology with low floors and high ceilings to reduce barriers and increase access to learning (Papert, 1980). Resnick and Silverman (2005) later expanded Papert’s low floors to include wide walls, emphasizing the design of technologies that support a wide range of exploration for learners. With Logo, children connected abstract computer science concepts with familiar images, such as a turtle, to solve problems in "microworlds" (or familiar scenarios), highlighting the process of learning through the construction of concrete, tangible objects (Anwar et al., 2019; Papert & Harel, 1991; Psenka et al., 2017). The most widespread use of Logo concepts was MIT Media Lab's partnership with the LEGO group to create the LEGO Mindstorm line of robotics hardware. Using physical LEGO construction kits allowed children to construct a more "active" computational model through programmable sensors that responded to a child's created scenario (Papert & Harel, 1991; Resnick & Silverman, 2005). For example, a robot may be constructed to sense light, heat, and time and react by changing the speed of motors that make up a car, snake, or other artifact. LEGO Mindstorms draws its name from Papert's 1980 book Mindstorms: Children, Computers, and Powerful Ideas. After years of development, LEGO Mindstorms' first commercial product line was launched in partnership with *FIRST* LEGO League (FLL) Challenge's inaugural competition season in September 1998 (Ames, 2018; Anwar et al., 2019; Benjamin, 2023).

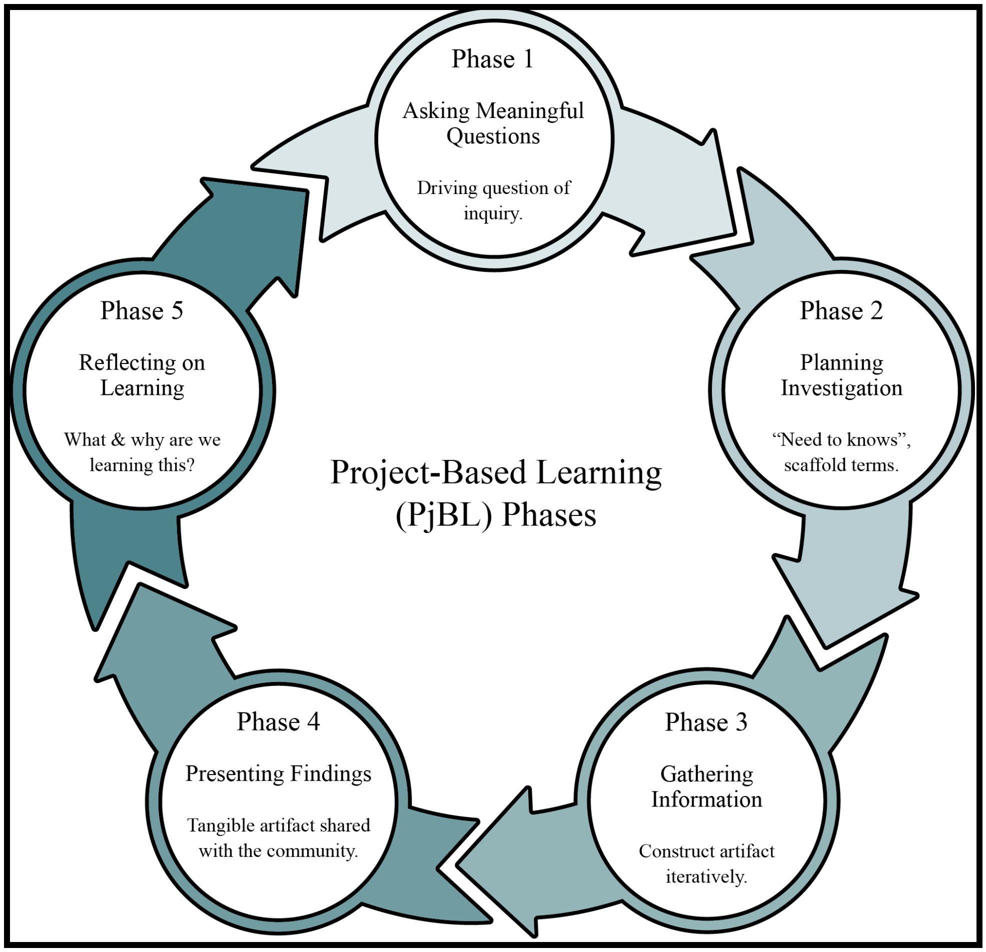
FLL Challenge increased the accessibility of educational robotics kits both in the classroom and in OST environments. Challenges followed constructionist frameworks, providing real-world problems to students and supporting emerging educators in implementing sustained creative problem-solving. Though the first constructionist projects targeted the domains of mathematics, programs such as FLL Challenge expanded the opportunity for learners to engage with interdisciplinary STEM subjects (Psenka et al., 2017). FLL Challenge fosters creativity and learning excellence through competitive developmental challenges and builds a sense of design heuristics by collaborating with others to use materials in new ways (Alimisis, 2012; Anwar et al., 2019; Polishuk et al., 2012). As programs such as FLL Challenge have increased accessibility, educational robotics has shifted from primary classroom-based to include OST environments (Alimisis, 2012; Kafai & Burke, 2013). Though FLL Challenge was directly created in collaboration with the LEGO group's Mindstorms, all of *FIRST*'s leagues from K-12 (FLL, FTC, and FRC) are rooted in constructionist methodologies. *FIRST* teams annually create an artifact (a robot) with clear curriculum connections to technology, language arts, and math courses (FIRST*,* 2022b; Yoel et al., 2020). Digitally, teams post 3D models of their robot, programming, and other resources in public forums, forwarding a collaborative culture of 'remixing' in a creative commons environment.

2.6.2 Project-Based Learning

Project-based learning (PjBL) is a student-centred instructional approach where students are presented with a long-term, interdisciplinary problem statement to which students respond by constructing a solution (Alberta et al. Resources Branch, 2004). PjBL allows learners to concentrate on applying concepts, experiences, and tools to research and solve real-world problems (Blumenfeld et al., 1991; Lee, 2018). The foundation for curricular foundations that support PjBL instruction was first laid by Dewey's (1902) observations that children effectively develop habits of inquiry under the guidance of learning experiences (Dewey, 1902; Lee, 2018; Sahin, 2013). Unlike methods of instruction where problems are used as a summative evaluation of a student's learning, PjBL opens the topic of interest with the problem and uses it to drive course content through extended inquiry, often presented by a larger organization or community member (Kokotsaki et al., 2016; Lee, 2018; Lee & Galdino, 2021). Bruner (1961) defined this type of learning as a process where students explore their questions through a series of phases: (1) asking meaningful questions, (2) planning investigative strategy, (3) gathering information, (4) presenting their findings, and (5) reflecting on their learning. A visualization of the phases of PjBL, as described by researchers, is illustrated in Figure 2.1.

Figure 2.1

Project-Based Learning (PjBL) Phases



With the expansion of constructivist principles of learning, researchers began to define PjBL as the construction of learners understanding through the creation of socially constructed artifacts involving the support of educators and mentors (Blumenfeld et al., 1991; Helle et al., 2006; Lee, 2018; Sahin, 2013). PjBL instruction supports students in constructing their understanding of academic content alongside educators through precise goal setting and agency over sequence and pace of learning (Helle et al., 2006).

While *problem*-based learning (PBL) encourages students to independently produce and explore research questions, PjBL presents learners with a guiding question and the context for their research (Sahin, 2013). PjBL's situational learning allows educators to present information to learners in the context of problem-solving, constructing the meaning of tasks that students are asked to perform (Blumenfeld et al., 1991; Lee, 2018). In contrast to instructional models that use classroom time for lecturing and textbook use, PjBL educators focus on curating classroom cultures of student self-management, group collaboration skills, and productive use of technological resources (Kokotsaki et al., 2016). Rather than being authoritative, educators practicing PjBL must create a flexible classroom culture. PjBL educators are encouraged to consider the implementation of their classroom culture intersectionality by considering power dynamics among student groups due to social class, gender and attainment hierarchies (Kokotsaki et al., 2016). Teachers experienced with PjBL focus on anticipating possible learning challenges and scaffold learning through activities that support student engagement without giving away the answer, such as class discussions and research investigation (Lee, 2018; Lee & Galdino, 2021). Students benefit from the PjBL environment by practicing practical presentation skills, listening to others, and using higher-order thinking instead of reciting subject-specific information (Lee, 2018).

Researchers have described best practices for the design of PjBL curricula specific to math (e.g. Lee, 2018; Lee & Galdino, 2021), science (e.g. Blumenfeld et al., 1991), and STEM PjBL (e.g. Burlbaw et al., 2013; Sahin, 2013). Through practical application, students are exposed to (and apply) subject-specific theoretical terminology, such as STEM engineering principles. Students participating in STEM PjBL programs or classes are encouraged to organize their schedule, division of tasks, and materials as a group, with just-in-time support from an instructor or mentor (Sahin, 2013; Yoel et al., 2020). Students are provided with opportunities to reflect on their learning through peer feedback and cycles of revision and must culminate their learning by presenting their artifacts to the classroom and larger community, such as FRC events (Dwivedi et al., 2021; Lee, 2018; Kokotsaki et al., 2016). Effective PjBL classrooms provide ample opportunities for students to actively explore the driving question through field-based activities and mentorship opportunities with greater community members (e.g. Lee, 2018; Koomen et al., 2021; Wickliffe et al., 2020).

For PjBL in STEM, students have a positive attitude toward learning and team communication and an increased STEM self-efficacy and subject interests (Witherspoon et al., 2018; Yoel et al., 2020). Studies have shown increased learner motivation in PjBL environments, especially for women constructing STEM artifacts (Kokotsaki et al., 2016). The interdisciplinary nature of PjBL projects allows learners to explore the connection of subjects to post-secondary and professional careers and reframing technology as a tool for communication, collaboration and learning (Burack et al., 2019; Kokotsaki et al., 2016; Lee & Galdino, 2021; Sahin, 2013). In STEM OST programs like FRC, students naturally engage with community partnerships with industry members in sustained mentorship. While an industry expert provides subject-specific support, the educator focuses on providing student ownership and input in creating their authentic artifact.

Educators can face implementation challenges for PjBL, including a need for prepared projects or training and administrative or community support (Aresi et al., 2020; Dwivedi et al., 2019; Lee, 2018). In the traditional classroom environment, the lack of available training materials, textbooks, and curriculum guides have prevented educators from implementing new PjBL units in their classroom (Lee & Galdino, 2021). For teachers new to the field of education, limited experience with pedagogical practice may inhibit educators from knowing when to provide student support during the inquiry process (Jin, 2021; Lee & Galdino, 2021). As PjBL expects students to explore the research, organization, and execution of their learning, a lack of confidence from an educator on when to provide just-in-time support may significantly impact the quality or effectiveness of a PjBL project's execution. These challenges are not limited solely to the classroom, as lack of confidence due to limited pedagogical experience or training in OST environments has impacted cases of robotics team performance (e.g. Dolenec et al., 2015; Kekelis et al., 2017).

Educator engagement in annual programs founded on the principles of PjBL could reduce the impact of the challenges mentioned above. For example, programs such as *FIRST* provide educators with robust, clearly defined student projects and a community of support and classroom resources for educators (FIRST, 2021b; Yoel et al., 2020). FRC's semester-based program schedule (January - April annually) provides predefined project constraints without needing educator development time. Further, students compete to create a culminating artifact (a robot) and present their learning journey in written and verbal presentations to judges, who evaluate student communication. During competitions, educators and mentors can meet with like-minded peers, providing ample opportunities for a culture of like-minded peers to discuss PjBL implementation.

2.6.3 Communities of Practice

Communities of practice (CoP) described the relationships between apprentices and masters in developing learning theory (Lave & Wenger, 1991; Wenger-Trayner & Wenger-Trayner, 2015). Though initially developed by analyzing the act of learning in formal mentorship environments, communities of practice are not limited to novice learners. Instead, it is a dynamic community of members engaged in collective practice within a given subject of interest. Communities of practice are "groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly" (Wenger-Trayner & Wenger-Trayner, 2015). Similarly to the roots of CoPs, FRC mentors and mentees may adopt an apprentice-expert relationship, where experienced volunteers train students as they collectively construct a robot. A community of practice has three main parts: (a) a domain, (b) a community and (c) a practice (Figure 2.2).

A. *Domain*: A shared topic of interest that defines a given community. A domain is not limited to a single job or role and can be narrow or broadly defined depending on a community.

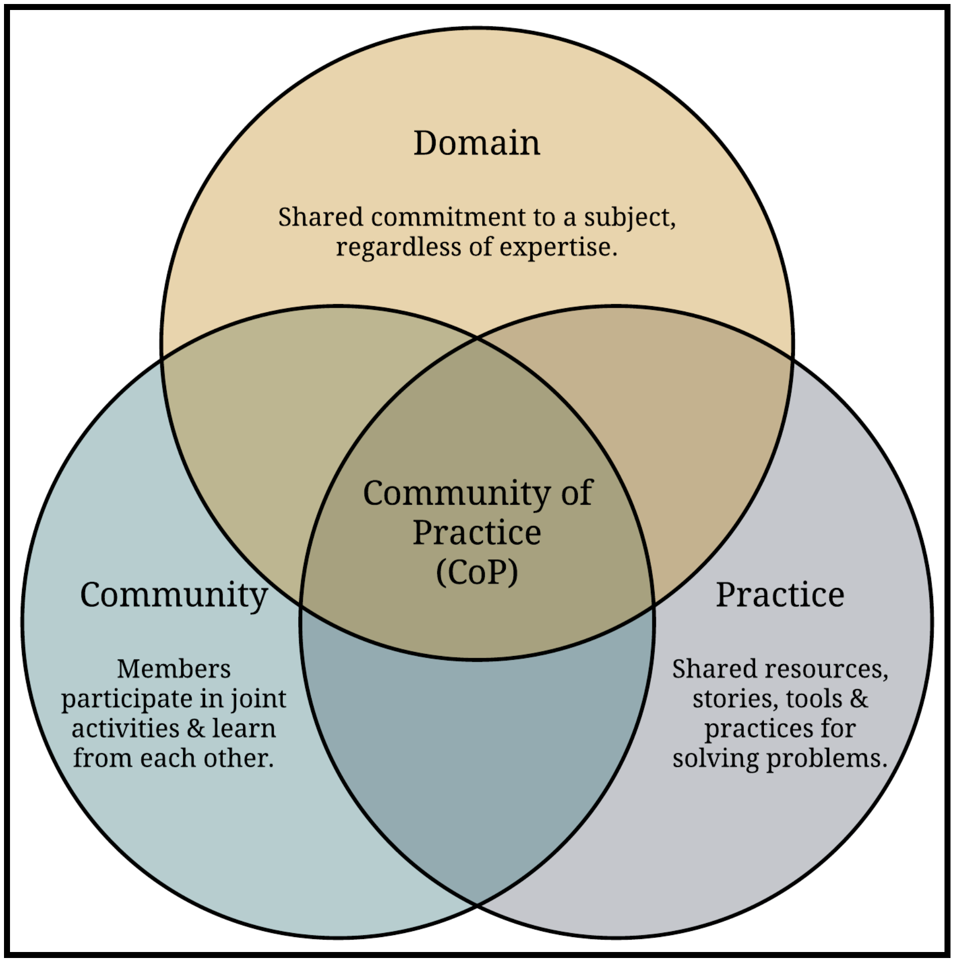
B. *Community:* The group of people involved in the practice over an extended period. Communities are developed through voluntary membership, such as participation in a club, rather than mandated commitment as with a job.

C. *Practice:* The practice is combined learning, experiences, and resources in response to collectively defined challenges and structures. A practice includes the understanding of personal, psychological, and technical demands associated with the challenge.

While all CoPs require a domain, practice, and community, they are flexible in size, meeting format, and formality. CoPs are inherently social, requiring the transfer of knowledge from experienced practitioners or existing knowledge to be transferred to novice practitioners. Communities of practice approach a problem under situated learning theory, which explains learning as an unintentional process expressed by legitimate peripheral participation (LPP). Using LPP, novice learners gain knowledge; they move from the peripheral of a community to its center, actively engaging in the sociocultural and technical practices within a community (Lave & Wenger, 1991).

Figure 2.2

Communities of Practice (CoP)



Note: Adapted from descriptions of the theory described in Lave & Wenger, 1991; Wenger et al., 2023.

Within the field of education, CoPs are used in peer-to-peer professional development activities and internally investigate how to organize educational experiences for students, identify how to connect with students' external experiences outside of the classroom, and how to engage students throughout their lives by developing topics of interest (Wenger-Trayner & Wenger-Trayner, 2015). As a social learning theory, CoP shares existing knowledge and invents new practices to advance innovation within the practice's domain. For OST STEM programs such as *FIRST*, mentors similarly organize educational experiences for students in the structure of their team meetings and core values (Davis et al., 2021) through the promotion of non-graded experiential projects guided by *FIRST*'s annual project-based learning prompt (FIRST, 2021b; Yoel et al., 2020). Rather than an "expert" serving as an instructor formally transmitting knowledge to novice practitioners, CoPs thrive in the informal transfer of knowledge through conversational "shop talk" (Wenger-Trayner et al., 2023). CoPs question the community's practice and authentically forward knowledge surrounding the given domain. Social learning activities within a CoP should be free of formal pedagogical activities associated with instructional-based webinars and presentations (Wenger, 1998; Wenger-Trayner et al., 2023). As a community, practitioners are encouraged to identify individual stories within a practice, understand how to engage with its members and identify struggles that the community is collectively struggling with to bring value to a challenge. As a practice, members are actively encouraged to create a socially safe environment for practitioners to present diverse perspectives and to question existing knowledge healthily.

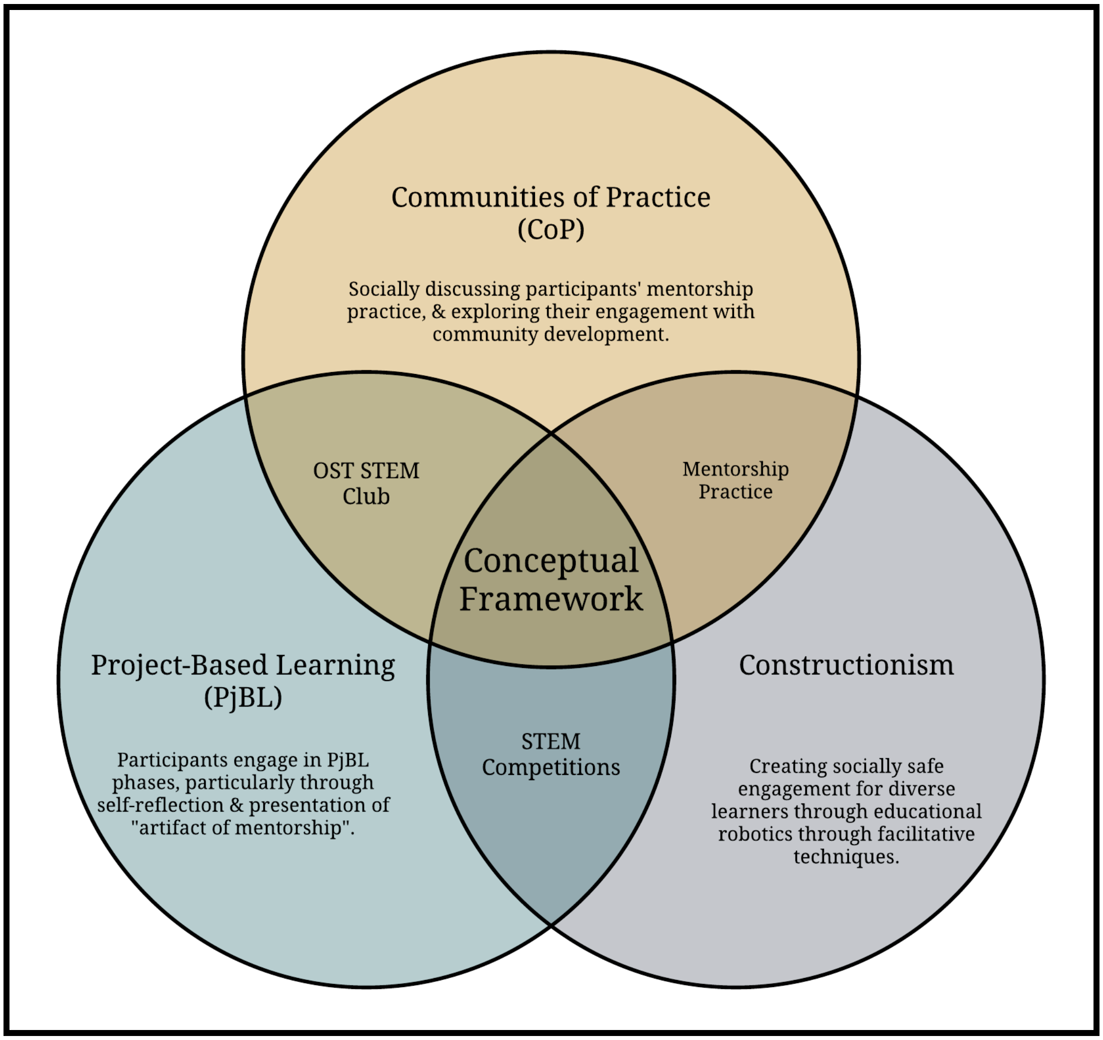
Within *FIRST*, communities of practice are identified by researchers within several domains, including *FIRST* as an organization, FRC teams meeting at a competition, and an individual FRC team (e.g. Davis et al., 2021). Researchers such as Verma (2015) frame LPP through "acts of authentication," quantifying FRC students' engagement in the sociocultural and technical nature of robotics competitions through the use of technical language at a robotics competition. Mentors and students equally engage with a team's CoP as community members, demonstrating their shared commitment to the practice through the authentic subject (domain) specific language (Verma, 2015). In a resource-rich competition setting, practitioners (students and mentors) engage in shared discussions surrounding the collectively defined challenge (the co-constructed robot), utilizing subject-specific terminology to communicate effectively (Hennessy Elliott, 2020). A mismatch or change in previously defined challenges can cause confusion and team cohesion challenges between students and mentors. Both in competitive and sessional OST youth programs, mentors' sudden changes in expectations can confuse students and create barriers to students' ability to integrate into the CoP as novice practitioners (Dwivedi et al., 2021).

2.7 Conceptual Framework

Where a theoretical framework seeks to explain and predict general more broadly than a single study, a conceptual framework illustrates the relationship of concepts specific to the research in question (Cohen et al., 2018). The constructionist, project-based learning, and community-of-practice theoretical frameworks were adapted into practical approaches to develop the study's methodological approach, allowing a more focused analysis and synthesis method. Figure 2.3 visually illustrates how the interconnected theories guided the study's research practices and analysis.

Figure 2.3

Research Design Method with Conceptual Framework



FIRST's established engagement with MIT media lab's theoretical development of educational robotics and constructionist theories (Anwar et al., 2019; Alimisis et al., 2009; Penska et al., 2017) has established a community of learners in a community of practice (Lave & Wenger, 1991; Wenger-Trayner & Wenger-Trayner, 2015). The main theoretical underpinnings of educational robotics competitions are project-based production, presentation, self-reflection of learning artifacts, and constructionist methodologies (Papert, 1980; Papert & Harel, 1991). The strategy for this research project was to engage in dialogue within the FRC mentors' community of practice in my role as a fellow practitioner (Verma, 2015; Wenger-Trayner & Wenger-Trayner, 2015; Wenger-Trayner et al., 2023). The act of self-reflection and the engagement in the social production of knowledge readily explore PjBL and constructionist frameworks. However, participants' unfamiliarity with theoretical underpinning and the study's limitation for the extended inquiry (Almisis, 2012; Noss & Clayson, 2015; Psenka et al., 2017) process required the adoption of CoP frameworks as a pedagogical approach. This combined conceptual approach allowed for the maximum presentation of constructed artifacts while engaging in the healthy questioning of the existing CoP through socially engaged "shop talk" (Wenger et al., 2023). The strategy for this research project was to engage with FRC mentors' understanding and practices related to EDI community development through the self-reflections of their practice and presentation of constructed artifacts.

3 Methods

3.1 Overview

This chapter reviews the design, methods, and analysis used in the research. Through several virtual interviews, participants across Ontario shared stories of their experiences as volunteer STEM mentors. Participants also generated and shared artifacts of their mentorship practices in journals, videos, photos, and submitted documents. Due to the open-ended and flexible nature of FRC mentorship, I used qualitative data collection methods in this study. These methods addressed the following research questions:

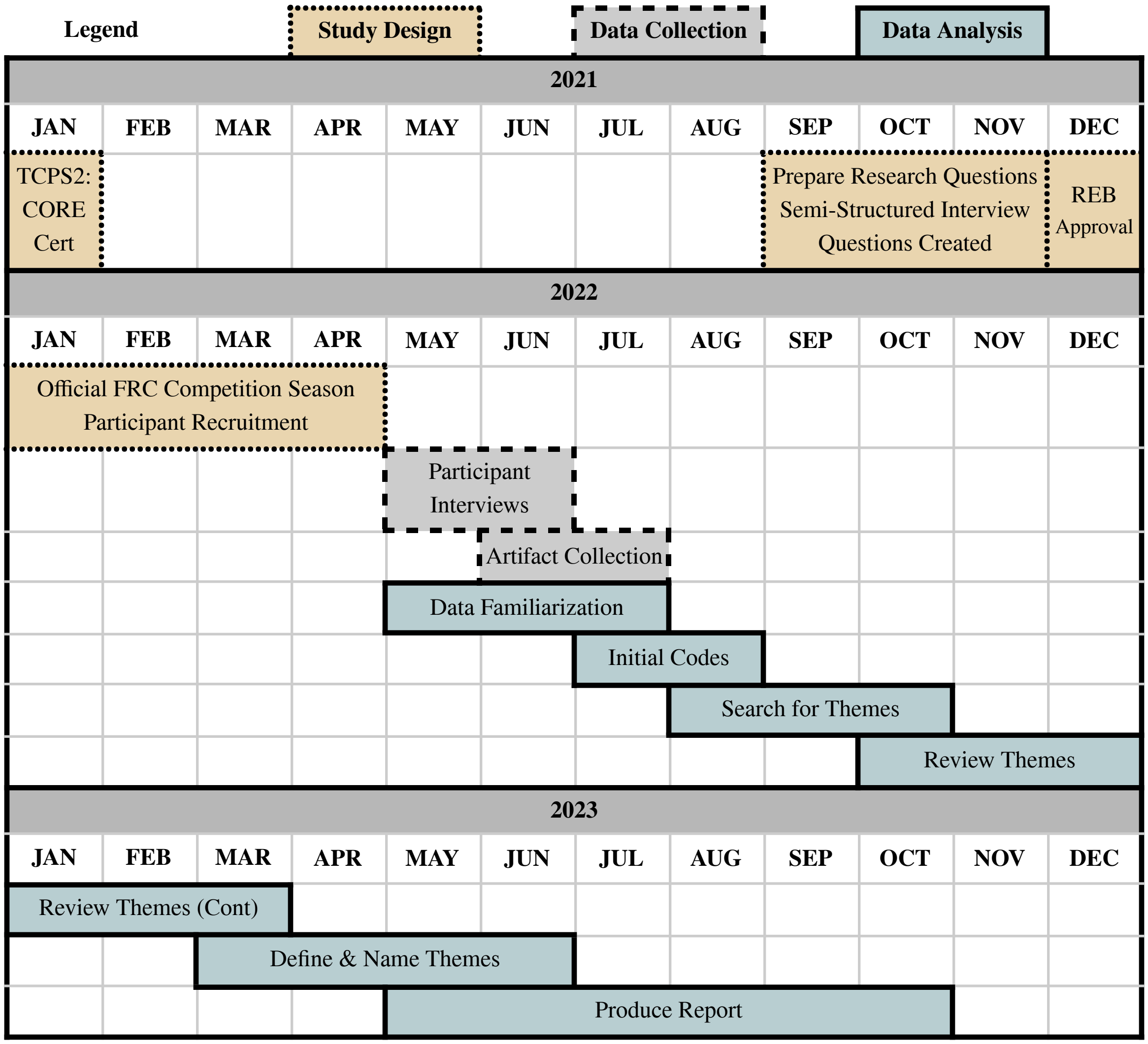
1. How have individual participants' mentorship approaches of grade 9-12 robotics teams evolved throughout their time as mentors?

2. What approaches do mentors use to develop a sense of community, particularly for underrepresented populations participating in grades 9-12 competitive robotics teams?

The research presented in this thesis report on the design and findings associated with mentor interviews and submitted artifacts, which took place digitally from April 27, 2022, to June 1, 2022, after the official FRC 2021-2022 competition season officially concluded on April 23, 2022. A complete overview of the study's stages and the order of events is illustrated in Figure 3.1.

Figure 3.1

Research Study Timeline



3.2 Design

3.2.1 Research Design

As the intersection of mentor identity and applications of STEM mentorship is a relatively understudied phenomenon, qualitative research supported the presentation of rich, descriptive accounts of participant experiences (Creswell, 2013). In case studies, the researcher must serve as an interpreter, reporting how knowledge is constructed to make sense of their experiences. Within the qualitative case study framework, I explored the research questions using a collective case study methodology, in which each participant was a case within the bounded context of volunteer mentors of FRC teams who participated in the 2021-2022 Ontario Provincial Championship FRC event (Creswell, 2013). Using multiple cases can strengthen the validity and trustworthiness of the findings (Miles & Huberman, 1994). Stake (1995) defined collective case studies as one of three types of case study, where multiple cases are compiled within a single context to identify insights into a research question. In alignment with my theoretical framework (2.6), I selected Stake's case study methodology for this study. Stakian case studies are rooted in the Social Constructivist epistemological stance, believing knowledge is constructed rather than discovered (Stake, 1995). As case studies are interpretive by nature, there is a potential for researcher bias presented in the study. I selected the mentors highlighted in the cases based on my identification of overarching themes in response to the research questions and presentation of rich, detailed data.

I conducted this research as a collective case study contextualized within the 2021-2022 FRC season. All participants actively supported FRC teams who participated in the 2021-2022 Ontario Provincial Championship event, which took place from April 13 - April 16, 2022, at the First Ontario Centre in Mississauga, Ontario. Due to COVID-19 gathering restrictions, during the 2021-2022 season, teams were limited by the capacity of representatives of students and mentors at events. As such, eligible study participants did not have to attend the 2021-2022 Ontario Provincial Championship event physically; however, they had to have actively supported an Ontario-based FRC team during the active season and have mentored an Ontario-based FRC team in at least one season prior to 2021-2022. I used purposeful sampling (Patton, 2002) when selecting participants in the cross-case analysis to fully describe multiple perspectives about the cases (Creswell, 2013). I prioritized the selection of diverse cases with rich data to provide a better opportunity to identify phenomena within the context of the cases. The six selected cases provide rich, insightful data that created a narrative of multiple cases surrounded by a single program (Creswell, 2013; Merriam, 1988).

The context of this study was developed using thematic analysis, where data collection methods included observations (of participants' interactions during their interview), pre-study questionnaires, semi-structured interviews, and the collection of digital artifacts (annotated photos and videos, written journal entries and essay submissions). For data analysis, I followed Saldana's (2016) recommendations for both In Vivo and artifact coding methods for diverse mediums. In Vivo coding was selected to preserve the participants' voices throughout identifying themes, preserving rich descriptions required by the Stakian case study methodology. As I coded data, I inductively developed themes to prevent potential bias from forming during the data analysis phases. Thematic data analysis was informed following Braun & Clarke's (2006) six phases of analysis, where I created and refined a thematic map (Figure 3.5) that visually identified themes within the data. The research is not intended to create generalizations about FRC mentorship but to present a glimpse of STEM mentors' lived experiences concluding the 2021-2022 Ontario FRC season. The context of this research was planned in hopes of contributing to the body of literature on critical STEM mentorship for volunteers.

3.2.2 FIRST Robotics Competition (FRC) Team Structure

A significant benefit to *FIRST* Robotics Competition (FRC) teams is the ability to support the adaptive infrastructure of a team's operations. Mentors may choose to structure their team in a school or community environment in one of the following ways: (a) in the classroom, (b) throughout lunch periods, (c) as an after-school or weekend club, and (d) as a community organization. For this study, mentors who have supported a broad range of teams were recruited.

Each FRC team has individual applications to (a) organizational structures, (b) mentor-to-student ratio, (c) areas of expertise, and (d) division of tasks. However, all teams around the world orient themselves towards an annual project-based learning challenge revealed annually in January. Mentors often structure learning throughout a cyclical 8-12 month period, recruiting and training students, supporting the production of a competitive robot, attending competitions, and supporting their greater community through socially responsible initiatives (FIRST, 2021b).

Mentors may support teams non-technically with essay and grant submissions, presentations, production of media content, and administrative duties heavily surrounding the problem-based season theme. In the 2021-2022 FRC season, teams competed in the game "Rapid React," whose theme encouraged teams to "re-imagine faster, more reliable, inclusive, and sustainable transportation innovations that better connect and grow communities and economies around the world" (FIRST, 2022a). This season aligned with the UN Sustainable Development goal #9, to "[b]uild resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation" (United Nations, 2021).

Through the production of a robot, technically minded mentors support the annual response to FRC's project-based challenge. In the 2021-2022 season, teams were provided with the problem of building a robot that may perform the tasks outlined in Table 3.1. With the guidance of mentors, each team produces a unique robot for the annual challenge theme. As I am a Lead Mentor of two local FRC teams from the same school, I provided illustrative examples (Figure 3.2, Figure 3.3) of FRC robots from the 2021-2022 season. For both Team A and Team B, students are recruited from the same area, with the same demographic backgrounds, and the same mentor volunteers, yet construct different artifacts in response to *FIRST*'s annual project-based challenge. Considerations for the varied team competitive performance and resulting team culture when controlling student and mentor recruitment are explored in Chapter Five.

Table 3.1

2021-2022 FRC Robot Objectives

Period	Time to Complete	Objective	Points
Pre-programed (autonomous)	15 seconds	Driving across a tape line	2
		Scoring ball in high goal	4
		Scoring ball in low goal	2
Driver-operated (teleoperated)	75 seconds	Scoring ball in high goal	2
		Scoring ball in low goal	1
End game	30 seconds	Climb rung 1	4
		Climb rung 2	6
		Climb rung 3	10
		Climb rung 4	15

Figure 3.2

2021-2022 FRC "Team A" Robot

Figure 3.3

2021-2022 FRC "Team B" Robot

3.3 Participants

Participants were recruited at *FIRST* Robotics Competition events in Ontario throughout the 2021-2022 competition season via email communication facilitated by *FIRST* Robotics Canada, with Lead Mentors, and by word-of-mouth. Active and retired FRC mentors across Ontario were invited to participate in the study, which took place virtually to reduce employment-related barriers associated with collecting data in person. All participants have been active mentors of at least one FRC team in Ontario and were over 18 during the interview.

Study recruitment remained open from January to May 2022 (Figure 3.1). I provided all interested mentors with a letter of information about the study and a consent form to be completed before completing an interview, survey, or submitting artifacts (Appendix B). As outlined in the letter of information, mentors were welcome to discuss their mentorship practices without participating in the research component. However, consent for both audio and video recording, as well as inclusion in the study, was freely given by all mentors who participated. This resulted in eight participants of diverse professional backgrounds, gender identities, ages, locations, cultural upbringings, disclosed disabilities, and experience with mentorship.

According to pre-survey data, there was an average of 6 years of mentorship experience among mentors, ranging from 1 to 15 years. Five of the eight participants identified as *FIRST* alumni, with personal lived experience participating in FRC for at least one year in high school. Of the remaining three mentors, one each identified as a mentor representing industry (engineering profession), a teacher (high school) and a parent of a child on an FRC team. Participants demonstrated a wide range of monthly contributions as a mentor to their FRC team despite the 2021-2022 FRC season challenge operating with gathering restrictions due to COVID-19 safety protocols. Four participants mentored their team an average of 4-12 hours per week, three mentors volunteered 1-3 hours per week, and one mentor volunteered an average of 13-25 hours per week. A full breakdown of the number of hours mentored per month, type of mentorship identity, and the year that each participant began mentoring is illustrated in Table 3.2

Compared to previous seasons, all mentors described their participation in the 2021-2022 FRC season to be less than their typical weekly contribution to an FRC team as a direct result of COVID-19 restrictions. Seven of the eight participants had an established professional relationship with me as a fellow *FIRST* mentor and volunteer for at least two years before the conduction of the study. Though an established working relationship was neither a selection criterion nor a recruitment method for this study, the existing rapport resulted in natural familiarity during 1:1 interviews and through the artifact collection process. A summary of the study's total participants, organized alphabetically by pseudonyms, is presented in Table 3.2.

Table 3.2

Summary of Participants

Pseudonym	Gender	Pronouns	Mentoring Since	Mentorship in Past 12 Months	Mentorship Type
Amelia	Woman	She/Her	2018	20-50 h/mo	Industry
Brinn	Woman	She/Her	2013	20-50 h/mo	Alumni
Cade	Man	He/Him	2015	50-100 h/mo	Teacher
Claire	Woman	She/Her	2006	20-50 h/mo	Family
Jace Hammervik	Genderfluid	They/Them	2020	20-50 h/mo	Alumni
Joel	Man	He/Him	2017	<10 h/mo	Alumni
Kamal	Man	He/Him	2015	<10 h/mo	Alumni
Megan	Woman	She/Her	2016	<10 h/mo	Alumni

Note: For this study, all pseudonyms were researcher-selected, except for Jace Hammervik, who self-selected their alias during the interview and artifact collection process.

Although a complete data set was collected from each of the eight registered participants, the number of participants included in the study was reduced through purposeful sampling. As all eight participants had a complete data set, prioritizing detail-rich, diverse cases allowed me to describe multiple perspectives in the study thoroughly (Creswell, 2012). Following best practices for collective case study research, I reduced the participant pool to allow for an in-depth analysis of each case and to conduct cross-case theme analysis (Creswell, 2013), including many perspectives through maximal variation sampling and highlighting both confirming and disconfirming cases

(Creswell, 2012; Saldana, 2016). As a result, three participants per research question (2.5) were selected to illustrate in-depth, illustrative findings in response to the study's two research questions.

I highlighted the selected participants for their ability to address the research questions in as much depth as possible (Miles & Huberman, 1994; Stake, 1995). These prioritizations allow for considerations of similar activities in youth mentorship program environments. In Chapter Four, I provide an overview of the insights of each research question by the complete participant pool, followed by an in-depth analysis of themes identified in individual cases.

3.4 Virtual Context

Due to provincial health regulations regarding COVID-19 and a desire to increase the accessibility and diversity of study participants, the interviews were held entirely digitally. Throughout the scheduling process, several participants consented to share personal stories of their daily lives, including rural and remote living quarters, limited mobility, and limited scheduling flexibility as family caregivers. Notably, the flexible nature of the virtual meeting platform, as well as my flexibility to schedule interviews at the time that participants were individually most comfortable with, allowed for increased diversity of participants. Before the interviews, participants were sent an informational email containing links to the Zoom meeting room and information about logging in. The interviews were held in Zoom due to its ability to produce a transcript and the availability of live closed captioning services. Participants could suggest a meeting software with which they were more comfortable or familiar—however, all preferred Zoom.

Though all participants consented to audio and video recording, using a camera and microphone throughout one-on-one discussions remained flexible for each participant. Participants used the meeting chat function and screen sharing for particular interviews while discussing their experiences. Screen sharing was beneficial when describing videos or digital artifacts that mentors had produced while on a robotics team.

3.5 Data Collection Tools

Using multiple data sources allowed for triangulation (Creswell, 2012; Patton, 2002) and provided a complete understanding of participants' unique mentorship experiences. The ability to triangulate multiple data sources supports the increase in validity and identification of developing themes throughout the collective case study. In line with Stakian case study best practices, the use of triangulating data sources supports the accurate depiction of the case and interpretations of their relation to the research questions (Stake, 1995; Yazan, 2015). I collected questionnaires, observations of nonverbal behaviour during interviews, semi-structured interviews, and artifacts throughout the study to inform the research questions. The connection of each data source to the study's research questions has been outlined in Table 3.3.

Table 3.3

Alignment of Data Sources to Research Questions (RQ)

Data Source	RQ 1	RQ 2
Pre-study questionnaire	X	
Participant observations	X	X
Semi-structured interviews	X	X
Collected artifacts (i.e. essay submissions, photos/videos, written reflections)	X	X

3.5.1 Pre-Study Questionnaire

A qualitative pre-study questionnaire was designed using Google Forms, which was sent to all participants virtually for asynchronous completion after receiving signed consent to the study. Except for two participants (Cade & Brinn), all completed the pre-study questionnaire before their 1:1 semi-structured interview. The final questionnaire (Appendix C) contained 18 questions: eleven about the participant's general demographic information and general mentorship familiarity, five about the participant's *FIRST* Robotics Competition teams mentorship, and two about their broader participation in *FIRST* programs.

All questions were optional to account for any potential impact of the response rate and level of detail. Questionnaires length or type of questions on the mentor's response quality, I ensured all questions were optional and under 15 minutes to complete (Saleh & Bista, 2017). Three participants chose not to disclose their cultural background, and one chose not to disclose the presence of visible or invisible disabilities. All participants completed the remainder of the questions in total, with elaboration. Though all mentors consented to complete the survey asynchronously and digitally via the Google Form, participants were informed of additional options to complete the survey either verbally or printed, should they prefer.

Demographic information and details about participants' frequency of mentorship per month created a context in which their experiences and stories could be situated. Two questions probed experience with other youth mentorship and STEM programs and familiarity with mentorship or pedagogical practices. Two questions investigated mentors' perceptions of belonging and identity, asking what type of mentor they identify as and where their identity has formed. Two additional questions examined mentors' self-efficacy related to mentorship, explicitly asking how experienced they feel at FRC mentorship and detailing perceptions of their contributions to the *FIRST* community.

3.5.2 Participant Observation

During and immediately concluding interviews with participants and observations throughout participant interviews were recorded to highlight interactions and points of note and to support data triangulation from other sources (Creswell, 2012; Patton, 2002). I recorded these observations via digital note-taking in tandem with semi-structured interviews. Using a digital note-taking device as the preliminary source of interview notes allowed quick thoughts to be recorded while facilitating continued conversation with participants (Creswell, 2012; Miles & Huberman, 1994; Saldana, 2016).

In-the-moment observations were primarily dot jots, highlighting meaningful comments, contextual non-verbal cues, and ongoing research themes during participant interviews. Immediately concluding each interview, field note dot jots were expanded upon, refined, and stored virtually in a Google Drive folder.

3.5.3 Semi-Structured Interviews

Semi-structured interviews were conducted one-on-one with each participant virtually at a time that was most convenient to the participant. Each participant met individually with me for a 60-90 minute conversation. Ten open-ended questions (Appendix D) guided each interview and were provided to participants in advance to allow time for questions. I prioritized open-ended questions to encourage participants' individual experiences with mentorship, allowing mentors to expand in depth and their own words. While each interview was scheduled for 90 minutes, the schedule and order of each question were left open to the participant, allowing flexibility for each conversation to explore unique experiences and perspectives on mentorship. All interviews were conducted using Zoom meeting software, which featured a recording option and auto-generated audio transcripts with timestamps. Using auto-transcripts and recording functionality allowed for passive data collection, enabling me to converse actively with each participant (Creswell, 2012; Miles & Huberman, 1994; Saldana, 2016). Following each interview, recording transcripts were verified for accuracy and stored privately on Google Drive before undergoing data analysis.

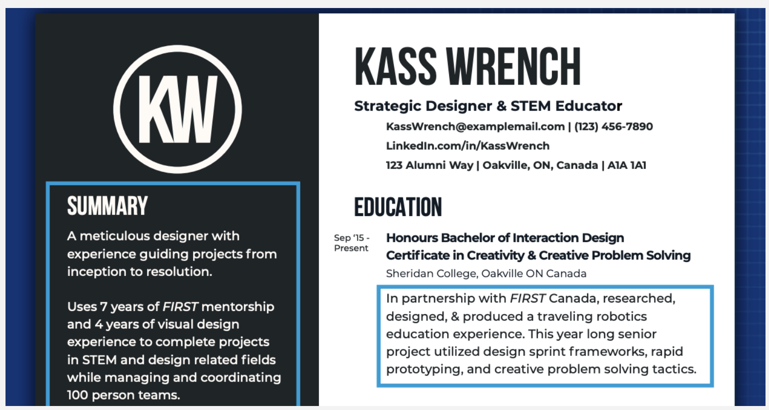
3.5.4 Artifact Collection

The submission of mentorship artifacts was optional for participants and produced artifacts during and concluding semi-structured interviews. As each participant serves a unique role as a mentor, and mentors had varied experience levels, artifacts varied from code snippets, videos, administrative documents, and journal entries about mentorship rationales. To support and validate the reflexive process, I verbally provided bullet point examples in my request for artifacts (Appendix E) to mentors. I then followed up with a personal example upon request by some participants (Appendix F). Examples of artifacts collected in each type of artifact are provided in Table 3.4. While some artifacts, such as journal reflections, were created as a direct response to interview questions, other formats of submitted artifacts varied based on each mentor's role for their team, including code snippets, essay nominations, and mentorship handbooks.

In addition to submitted artifacts from participants, after each interview, I identified and verified with participants copies of relevant material participants discussed in their interviews, such as videos and reference material produced by *FIRST.* Upon confirmation of reference material, participants provided written or verbal annotation as to the personal meaning of the source material and submitted this information as additional artifacts of their mentorship. A digital copy of each participant's selected artifact and included annotations, which I uploaded to a Google Drive folder for secure storage.

Table 3.4

Examples of Participant Digital Artifacts

Artifact	Example
Recruitment document	Becoming a Mentor How to become a mentor: 1. Meet with the Head Lead Mentor and/or faculty advisor to discuss where the team might best use your skills. 2. Read over the team handbook, guidelines and mentor handbook 3. Complete and turn in the Mentor Application in the appendix of the handbook. 4. Complete and sign team liability and waiver forms, as well as all online required forms. 5. Complete the WCDSB volunteer application forms provided by the faculty advisor or Head Lead Mentor and submit the application forms to the faculty advisor, together with your police background check. Mentor Selection The mentor committee (which consists of all Lead Mentors) will review and approve mentor applications. If mentorship position is approved, the WCDSB volunteer background clearance must be completed before becoming an active mentor. While this is occurring, prospective mentors may work with the team as an assistant mentor who is teamed with a current mentor.
Image with annotation	

Journal reflection	Mentoring methodology:
	• Trickle down mentoring, have more experienced students run workshops to teach the newer ones. For example, making a wiring tutorial, or explaining the control system of the robot.
	• For programming, there are 3 stages of students that I would mentally group.
	  ○ First is brand new, with little to no programming experience. With these students, I would try and do programming lessons, and guide them towards online lessons.
	  ○ Second are students with programming experience, but not robot coding. With these students, I would have them look at previous year code and wpilib to get the feel of how robot code works.
	  ○ Third is the experienced students who know robot code. With these students, the goal is to get them to push the boundaries, i.e. learn motion profiling, camera vision, etc. This would be done through looking at more online docs, and looking at tutorials that other teams had made.

Artifact	Example
Video with narration	

3.6 Ethics

Ensuring continued voluntary consent of all participants is essential for the respect of participants in a research study (Creswell, 2012;). Before the research planning stage, I completed the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (Canadian Institutes of Health Research et al., 2022) Course on Research Ethics (TCPS 2: CORE, Appendix I; Figure 3.1). Following the TCPS 2:CORE guidelines, I prioritized the core principles of respect for persons, concern for welfare, and justice throughout the entire design of this research.

During the recruitment process at FRC events, mentors were informed that there was a voluntary research component to discussions about their mentorship practices. Mentors received a follow-up email with information about the voluntary research component of the study after the competitions. Participants were contacted digitally to reduce the potential undue influence of feelings of time and location-based pressure associated with in-person recruitment processes (Canadian Institutes of Health Research et al., 2022). A copy of the initial mentor email (Appendix A) and consent form (Appendix B) were sent to all participants digitally via email before completing the pre-study questionnaire or scheduling interviews. Participants were informed of the nature of the study, the methods of data collection, participation risks, confidentiality and data storage policies, and the option to withdraw from the study at any time.

Following the letter of information, participants were asked to confirm assent to participate in the research and confirm each method of data collection that they consented to. All eight participants freely consented to the study, as well as audio and video interview recordings. Four of the eight participants consented to submit personal artifacts of their mentorship for inclusion in the study. I accepted consent forms via email and stored them virtually with private access to the researcher on a cloud server administered by the university. Pre-defined interview questions were provided well before their interview to decrease the power imbalance between researcher and participant and increase the study's transparency and participant comfort (Canadian Institutes of Health Research et al., 2022).

Participants reaffirmed their consent continuously through the study during the pre-survey (Appendix C), virtual interview process (Appendix D), and submission of digital artifacts (Appendix E). Throughout the study, I self-disclosed my experience as an FRC Alumna and Lead Mentor with participants (Appendix F), supporting TCPS2 recommendations to seek community engagement throughout the study's process (Canadian Institutes of Health Research et al., 2022).

I maintained contact with participants at all stages of the research process. I shared samples of my progress with them, ensuring continual consent from participants (Canadian Institutes of Health Research et al., 2022). Continual communication about any updates to all elements of the research, including the wording of research questions, methods of data analysis, and inclusion of additional theoretical frameworks, was provided to each research participant. In all cases, I prioritized accurately portraying participant experiences by describing both confirming and disconfirming experiences (Creswell, 2013).

3.7 Data Analysis

After collecting the data, all audiovisual data (i.e., interviews) were transcribed and analyzed with all textual data (i.e., pre-study questionnaires and artifacts). I designed the research as a collective case study informed by Stake's (1995) methodology. I selected data analysis approaches that complemented the construction of knowledge. To analyze the data, I followed thematic analysis procedures to interpret patterns of meaning in the qualitative data (Braun & Clarke, 2006). Using thematic analysis allowed me to identify patterns across participants' lived experiences and the ideal application of the tool to critical frameworks (Clarke & Braun, 2017). Informed by the theoretical framework of constructionism (2.6.1), I inductively constructed the meaning of the collected data (Creswell, 2013). I focused on collected artifacts and their representation as "social artifacts" (Saldana, 2016, p. 61), documenting the memos and their meanings among audiovisual data. The cyclical process of my data analysis reduced potential researcher bias and helped to preserve the participants' voices (Saldana, 2016). The following sections detail the thematic analysis procedures I underwent, informed by Braun & Clarke's (2006) best practices for this method, and visually illustrated in Figure 3.1.

3.7.1 Familiarization

First, I immersed myself in the data by actively reading and transcribing all audiovisual information in full into digital documents organized by interview participants. Through the interpretive act of verbatim transcriptions (including pauses and coughs), I began to construct the meaning of the data (Lapadat & Lindsay, 1999). Following Saldana's (2016) guidance for the coding of visual artifacts, I expanded upon jottings for each submitted artifact and entered codes into the same spreadsheet for each relevant participant transcript. This initial organization system allowed me to familiarize myself with the data and immerse myself in the individual participant's choice of words, use of gestures, and changes in emotion as they responded to questions. During this familiarization stage, I began manually highlighting words and phrases inductively for each participant independently for review in the following phase.

3.7.2 Initial Codes

Next, I manually and systemically worked through the entire data set to generate an initial set of codes in a first-impression coding style (Braun & Clarke, 2006; Saldana, 2016). Using In Vivo codes allowed participant data to use words and concepts from the participants in its most raw format (Braun & Clarke, 2006; Saldana, 2016). As I highlighted codes, I retained contextual information about the story to better develop themes in future analysis phases (Braun & Clarke, 2006). I inductively highlighted phrases for each mentor, transferring all of the highlighted phrases into a spreadsheet organized into meaningful groups by each participant (e.g. Table 3.5). As I grouped each piece of data, I kept the research questions (2.5) in mind, allowing me to ensure the development of relevant and meaningful codes. I followed Saldana's (2016) recommendations for familiarization by thoroughly reviewing each participant's data set before moving on.

Table 3.5

Examples of Highlighting Transcripts

Speaker	Transcript	Coding Notes
Katlin	When you approach mentorship, are there any skills that you focus on building in a team?	
Claire	I find it's really important to explain our team culture from the onset so that we're all on the same page because **I recognize that there's no one way to run a team. You have to make sure that they understand exactly what your goals and expectations are, and you know what you're willing to be flexible on.** So I find that's really important to do from the onset.	Varied team approaches
	I will go into the details of what that looks like for me, but that's the main thing when I mentor mentors.	
	For students, my first step is always to get to know them first. I find my mentorship style is much more tailored to the individual. It's important for me to get to know students to understand what they need.	Individual mentorship
	One student may need a lot of praise and recognition and encouragement, and another may have a huge ego that doesn't necessarily have the skills to go with it. Trying to temper those and keeping in mind the whole acronym of *FIRST.*	
	"For Inspiration and Recognition". That's always our goal. To inspire them to be the best they can be. I think that, once again, looks different for every individual. So I think it's important to be adaptable.	*FIRST* acronym Inspiration mentioned by Amber & Megan

3.7.3 Search for Themes

After completing the initial coding phase, I collated all relevant codes into broad, overarching themes. In this phase, I highlighted quotes from each participant and began developing the first coding cycle. Descriptive codes were developed inductively, starting with the data from the ground up (Braun & Clarke, 2006; Creswell, 2013; Saldana, 2016), and evolved as all participant transcripts were systematically reviewed and analyzed. Inductive coding was selected as the preferred method, as it is data-driven without trying to fit data into pre-existing coding frames or preconceptions (Braun & Clarke, 2006). At this stage, I sorted digitally using a spreadsheet, creating broad definitions for each theme in a table (Table 3.6) and an initial thematic map of themes (Figure 3.4). Initial data groupings were guided by the study's research questions (mentorship experience, pedagogical growth, and application of mentorship), ensuring that data groupings were relevant to the study. To avoid reliability concerns due to intercoder conflict, I independently coded and identified preliminary themes for the entire data set before seeking critical feedback from my peers (Creswell, 2013). I split In Vivo passages into multiple codes, keeping the contextual data surrounding each code following Saldana's (2016) guidance.

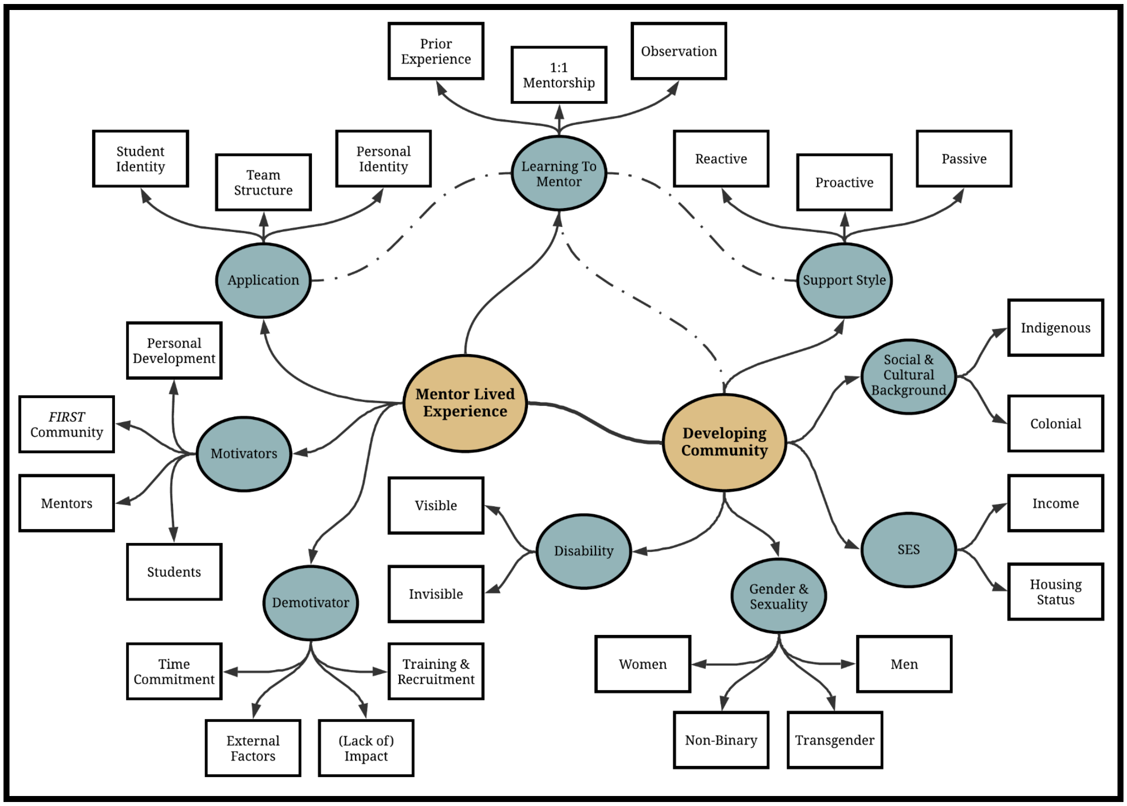
Table 3.6

First Coding Round Broad Themes

Category	Sub-Category
Things that make you want to stop mentoring	Mentor development & recruitment Time commitment to mentor Impact to team External factors, community focused
Things that make you want to mentor	Personal development Development of student skills / relationship Development of peer / mentor relationships Development of the larger STEM / *FIRST* community
Tactics or influences related to socioeconomic status, culture, disabilities, gender identities	Explicit consideration for EDI Discussing change & mentor techniques
How your mentoring has changed, qualities about mentors	Mentors mentoring mentors Learn through observation Prior experience & application
Information or qualities about the team, Describing work/life balance	Describing identity & factors of mentor life Describing students on the team Describing the structure of the team

Figure 3.4

Initial Thematic Map



3.7.4 Review Themes

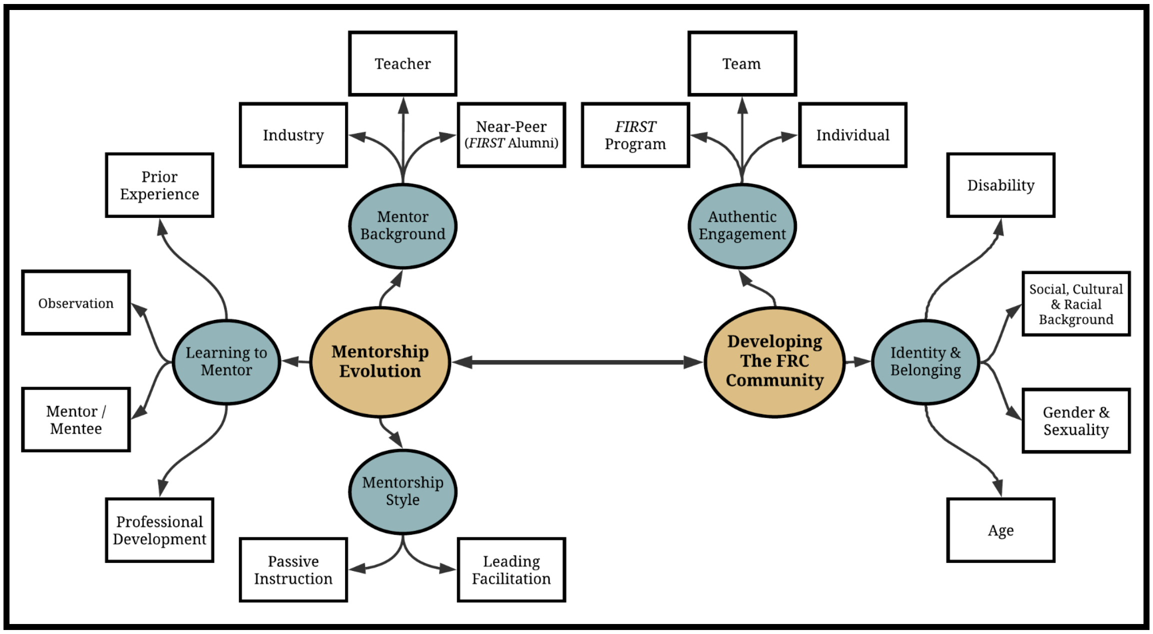
Once I identified all candidate themes in physical piles, I manually transferred the data to a spreadsheet, assigning each quotation to a theme and subtheme. I began to refine the themes identified, focusing on those relevant to the initial research questions and having rich data (Braun & Clarke, 2006). I carefully ensured that data between themes were distinct while verifying their connection to the original research questions (2.5). I verified patterns in contextual data extracted during the initial coding phase for each theme. Following Braun & Clarke's (2006) recommendation for refining themes, collated data that did not work into an existing theme were reworked or assigned a more appropriate one. Once I had refined individual themes, I began to consider the validity of themes concerning the whole data set. I reread the complete data set to verify that themes accurately reflected participant data and that no codes were missing from the initial coding phases. Before beginning subsequent data analysis cycles, I contacted participants to share initial coding progress following recommendations to assess the trustworthiness of initial codes through member checking (Creswell, 2013; Ezzy, 2002).

3.7.5 Define & Name Themes

Beginning Braun & Clarke's (2006) fifth stage, I began to refine the essence of each theme, developing clear definitions of each one. I began this process by creating a refined thematic map (Figure 3.5), which helped visualize the connection to each theme's research question and their relationship. Once I completed the thematic map, I documented each theme and subtheme, taking time to document operational definitions for each code (Appendix G, Appendix H). The two major developed themes included (a) the described growth of participants' mentorship experience over time, with sub-themes of mentorship background, learning to mentor, and mentorship style, and (b) the development of an FRC community, with sub-themes of identity and belonging, and authentic engagement of communities.

Figure 3.5

Refined Thematic Map



3.7.6 Produce Report

Finally, I organized this thesis's data excerpts and insights, carefully referring to links to existing literature (Braun & Clarke, 2006; Neundorf, 2018). Introducing my thesis, I provided descriptions of my position as a researcher and my personal experience with the subject, leading to an understanding of how my experience may have shaped the study (Creswell, 2013; Merriam, 1988). In designing and producing the study, I sought critical feedback from my peers, advisors, and participants to increase the study's reliability and validity (Creswell, 2013; Lincoln & Guba, 1985; Patton, 2002). I triangulated data by collecting multiple data sources, supporting the credibility of the study and its findings (Patton, 2002). Finally, following Stake's (2010) guidance for producing a case study, I ensured that I provided abundant, descriptive details about each case, describing interconnected details using strong action verbs and quotes (Creswell, 2013; Stake, 2010). Throughout the descriptions of each case, I provided detailed, thick descriptions that support the transferability of the cases to other educational or mentorship settings and a cross-case analysis exploring the significance of themes across cases (Creswell, 2013; Lincoln & Guba, 1985; Saldana, 2016; Stake, 2006).

In summary, I designed this thesis using a Stakian case study design aligned with the theoretical frameworks outlined in Chapter Two. The collective case study was bound in the context of the mentorship of Ontario FRC teams participating in the 2021-2022 FRC season (3.2.2). Eight participants (3.3) were recruited and interviewed virtually (3.4), all of whom freely and continually consented to participation in the research study (3.6). Patton's (2002) purposeful sampling was followed for data collection, prioritizing rich data across six unique cases of mentorship. Multiple data collection tools (3.5) allowed for triangulation, increased validity, and identified themes throughout the study. These tools included pre-study questionnaires (3.5.1), participant observations (3.5.2), semi-structured interviews (3.5.3), and participant-submitted artifacts (3.5.4). I maintained continual communication with my participants and sought feedback from my peers and supervisor throughout my research. Throughout multiple rounds of coding, I followed Saldana's (2016) In Vivo and artifact coding methods, inductively developing themes to avoid potential bias during data analysis. Following Braun & Clarke's (2006) six steps for thematic analysis, I concluded my study by producing this report.

4 Findings

4.1 Overview

This study explored how informal educators design inclusive communities at the high school level. Two research questions were designed that guided this study:

1. How have individual participants' mentorship approaches of grade 9-12 robotics teams evolved throughout their time as mentors?

2. What approaches do mentors use to develop a sense of community, particularly for underrepresented populations participating in grades 9-12 competitive robotics teams?

Research questions have organized the results below, highlighting individual cases using participants' pseudonyms (Table 3.2). As a complete data set was collected for all participants, triangulation of multiple data sources was possible for all cases in the study. Each section begins with an overview of the significant findings from all participants, followed by a comprehensive analysis of three cases. In line with the study's methodology (3), preference in case selection was given to cases that represented detailed and contextual descriptions in response to each question. The chapter concludes with a summary of findings for each of the study's themes (4.4), collectively discussed in the following chapter (5).

4.2 Engaging in STEM Mentorship

The first objective of this study was to explore participants' evolution of mentorship practices concluding the 2021-2022 FRC Ontario event season. Throughout interviews and participants' submission of artifacts, two themes emerged surrounding how they learned how to mentor (4.2.1) and the style of mentorship described by participants (4.2.2).

4.2.1 Learning to Mentor

In response to the pre-study questionnaire (Appendix C) that asked each of the eight participants to indicate their level of expertise with mentorship (Table 4.1), one responded "⅖," three responded "⅗," three responded "⅘," and one chose not to respond. When asked to describe their expertise, mentors who self-rated ⅘ shared that they were confident leading technical and non-technical projects and carrying out administrative duties on the team. One participant who self-rated ⅖ shared that they felt inexperienced as a mentor who has only been in the program for three years in the role of mentor. Participants also shared details about their role as a mentor on their FRC team, which included alumni mentorship (near-peer), industry or family members, and teachers (Table 4.2).

Generally, mentors who participated in FRC as high school students (five) felt more confident in their first season as mentors in program-specific systems such as coding, awards submissions, and electrical subsystems. Mentors who learned about FRC as a teacher (one), parent (one), or industry member (one) were more confident in interpersonal skills, conflict resolution, and communication than participants who identified as *FIRST* alumni. During interviews, all participants were asked the open-ended question: How did you learn to mentor? (Appendix D) Participant responses to the question varied based on their familiarity and introduction to *FIRST,* as illustrated by their self-described responses in the pre-study questionnaire. Participants in the study identified as alumni (near-peer mentors), industry professionals or family members, or formally trained teachers (Table 4.2). Though Cade identified as a teacher mentor and operated his team using school facilities, his participation on his *FIRST* team was unpaid, as with all other participants.

Table 4.1

Participant Self-Rated Mentorship Expertise

Pseudonym	Self-Rated Expertise	Expertise Reasoning	Additional Comments
Amelia	3/5	Been mentoring for several years in different roles.	FRC, [Team]-lead mentor, 50+hrs/month.
Brinn	N/A	N/A	Lead Queuer for FRC in Ontario, SOME experience with FLL as Pit [Admin] Supervisor and Judge.
Cade	4/5	Need technical skill development.	[Experience mentoring 10 *FIRST* Teams]
Claire	4/5	I have lots of experience but still have much to learn.	[Have supported] all *FIRST* programs.
Jace Hammervik	2/5	I am still very new, as this is only my third season.	Pit Announcer at [Two Ontario District FRC Events], 2022
Joel	3/5	I have been mentoring for FRC for a few years now. In doing so I have been able to develop my skills at working with students. At the same time I recognize that I still have many things to learn and many skills to develop along the way.	Team was not active this year due to COVID 19.
Kamal	4/5	Multiple years mentoring, helped with some admin tasks, know what it takes to build a robot and compete.	FTA, CSA, yearly, other roles more sporadically. Mentored [Two FRC teams], while offering help to other teams.
Megan	3/5	I believe I've mentored in multiple roles, some more technical than others. I believe this gives me some level of expertise but I'm always looking to learn more.	FRC LRI, 2-3 events per year since 2018.

Table 4.2

Participants' interview response: "How did you learn to mentor?"

Pseudonym	Type	Response to "How do you mentor?
Brinn	Alumni	I will be honest, in my first year as a mentor, I was horrible. I was [focused on competitive success and was] not focused on mentoring the students. I shouldn't have been a mentor. [...] I learned most of what I know now through watching and from experience.
Jace Hammervik	Alumni	I never technically learned how to mentor. I just jumped in with both feet. I was always in the leadership role on the team, even though it was mostly unofficial. I was always hands-on with a lot of stuff. So the transition happened naturally. [...] A lot of those things that are the key parts of how I mentor were something that started developing when I was in *FIRST* as a student.
Joel	Alumni	I wasn't given a lot of guidance on how to mentor because the [only other mentors were] teachers [and they were trained as educators]. They already had the skills to mentor. There was a lot of learning about what to say and how to say it. Knowing when it's appropriate to push a student to do more because you know they have it in them and when not to was an interesting challenge.
Kamal	Alumni	I think that time [on a *FIRST* team] in high school was a big thing for me mentoring and guided the way that I mentor.
Megan	Alumni	I think a lot of it in high school is that I dreamed of what it would be like if I had a good mentor. If I had mentors, what they would do, and what I would find helpful. I think a lot about that as a mentor: what would I actually find helpful to achieve the goals and the things I wanted to do in high school, and what was the support that I really needed?
Claire	Family	I found [an experienced *FIRST* mentor who] mentored me on [...] the more technical areas that I struggled with. Then I found a homeschooling group [locally who] mentored me in a different style.
Amelia	Industry	The first month [on the team] was very much focused on finding out what is mentoring about. Asking what are we doing here, what's the point, how do I deal with these high schoolers over an extended period of time. Our lead mentor [...] was awesome. She founded the team, and she was a really good resource to watch to see how she interacted with the students.
Cade	Teacher	If I knew there was a skill set, then you can learn it, but I don't think there's a skillset mentoring. I have a core belief that I enjoy seeing First Nations youth succeed [...] I want to see the project complete, and no matter what, they will have a robot driving on the field.

FIRST alumni who chose to continue mentoring closely related to their personal experience with mentors as an FRC student, sharing sentiments such as: “The key parts of how I mentor were something that started developing when I was in *FIRST* as a student” (Jace Hammervik) and “A lot of it in high school is that I dreamed of what it would be like if I had a good mentor” (Megan). Though alumni mentors could describe the benefits of mentors, they also reflected on their limited experience in applying a teaching practice compared to industry and teacher mentors. For example, alumni reflected on their first season as mentors by sharing: “In my first year as a mentor, I was horrible.” (Brinn), “I wasn’t given a lot of guidance on how to mentor because the [only other mentors were] teachers [and they were trained as educators]” (Joel). Though alumni participants commented about their self-described poor mentorship practices in their first season as a mentor, alumni participants unanimously described a process of extended inquiry as a means to evolve their mentorship practice over several FRC seasons.

Contrasting alumni mentors' self-guided extended inquiry, industry and teacher participants (Claire, Cade and Amelia) relied on one-on-one mentorship from more experienced FRC volunteers in their first season on a team. Through one-on-one guidance, industry and teacher mentors learned about team culture and mentorship expectations and had direct support when learning about technical specifications specific to FRC. After at least three seasons of mentorship in FRC, participants became more confident in their mentorship practice, regardless of their role as industry, teacher, or alumni mentors. While newer mentors (Jace Hammervik and Joel) described the process of seeking out one-on-one guidance from more experienced mentors as the central theme of their interviews, all other participants also discussed the training and recruitment of mentors, emphasizing the importance of hands-on training and providing written mentor handbooks to new volunteers.

4.2.2 Mentorship Style

In conversation, participants described their approach to mentorship as "hands-off" (Amelia, Jace Hammervik, Megan, Brinn), "student-led" (Amelia, Kamal, Megan) and "taking a step back" (Cade, Kamal, Brinn) to describe "ideal" applications of mentorship. In contrast, participants used phrases such as "directive" (Megan, Brinn), "assigning jobs" (Amelia, Jace Hammervik), and "handing off to students" (Kamal, Brinn) to describe ineffective mentorship practices on a team. In submitted artifacts, participants expressed their mentorship practices using more formal language than in conversation, using terms such as "Teaching Philosophy" (Brinn) and "Mentoring Methodology" (Kamal) to describe their approaches.

Participants who held a role as a mentor on more than one FRC team (Amelia, Kamal, Megan) described effective team leadership as "clearly structured" (Amelia, Megan), where mentors "filled a hole" (Amelia, Kamal). When asked to describe their mentorship approach, no mentor used terminology such as "pedagogy" or classroom approaches such as "project-based learning." Instead, general phrases like "team culture" (Amelia, Claire, Jace Hammervik, Brinn) and "goal of mentorship" (Amelia, Kamal) were used. Mentors frequently defined "success as a mentor" throughout their interviews and were closely aligned with the *FIRST* acronym to "Inspire" and build "Recognition of

Science and Technology" (Amelia, Claire, Megan). Further, the most commonly held belief was that competitive success is not a metric of effective mentorship on a team, which all participants expressed.

4.2.3 Case Studies

The three cases in this section were selected to represent youth robotics mentors' lived experiences concluding the 2021-2022 FRC season. As a Lead Mentor, Brinn articulated mentor recruitment and training practices for her team over many seasons. Amelia reflected on the influence of near-peer mentorship on her personal growth as a mentor and contributing factors to mentorship application between two FRC teams. Finally, Kamal reflected on the impact of FRC team motivation for competitive success on mentorship applications.

4.2.3.1 Brinn: Mentor Training Philosophy

> The team, to me, should be a social space. It should be a space where the kids can be kids: hang out, interact with people, and get those experiences. It shouldn't be a place where we just want to win. If that's the only reason you're here, you won't get much out [of the program].

Twenty-six-year-old *FIRST* Alumna with a Bachelor's in General Arts, Brinn has served as a mentor on her FRC team since 2013. As a Lead Mentor, Brinn was intimately familiar with recruiting and training fellow mentors and mentoring students on the team. As an Application Recovery Specialist and a Customer Experience Representative, Brinn worked two separate jobs outside of mentoring FRC. For eight years, Brinn has donated hundreds of hours as a volunteer for her team each season, spending 20-50 hours each month as a mentor in the 2021-2022 season. Brinn took mentorship of her FRC team seriously, sharing that "for the longest time, I felt like mentoring this team was like a second job, or in my case, the third job since I have two jobs." As a team, Brinn described the importance of ensuring that students do as much hands-on research, problem-solving, and building as possible while mentors provide guidance and encouragement (Figure 4.1). Outside of mentoring, Brinn volunteered as a Lead Queuer for FRC events, a key volunteer position directing teams' flow and ensuring that the event runs on schedule through teams arriving to their matches on time, and as an FLL Challenge judge.

Brinn's team was affiliated with a public Catholic high school, which served 960 students in the 2021-2022 school year (Ontario Ministry of Education, 2023). At the school, 30% of the school's student population lived in households below the poverty line, and 35% of students had a first language other than English (Ontario Ministry of Education, 2023). At home, 15% of parents had no post-secondary certifications (Ontario Ministry of Education, 2023). During the 2021-2022 season, Brinn's team was run by approximately ten dedicated mentors, with ten students regularly attending team meetings. Throughout her interview, Brinn reflected on her mentorship style, sharing that she has always preferred mentoring students individually rather than in a larger group setting. Brinn reflected further on her experience as a mentor on the team,

> It's also a little different now because I'm the oldest of the mentors except for [our Lead Mentor]. I have been on the team for the longest, so I have a different reputation. A lot of the current mentors I mentored as students, so it's a bit weird for me to change that through the process.

During her interview, Brinn compared and contrasted her mentorship as a recent graduate in 2013 with her mentorship in the 2021-2022 FRC season. Brinn's team designed a mentorship handbook she submitted as a pre-constructed artifact of her mentorship, highlighting mentor training practices and expectations. Brinn shared that the handbook "outlines what we expect from each mentor to consolidate a consistent mentorship style across the team." The manual also defines the difference between mentors (Figure 4.2, Figure 4.3) on the team based on the type of projects the mentor works on.

When she first started mentoring in 2013, Brinn was more hands-on with students than now. As a new mentor, she assigned tasks to students, guiding them step-by-step throughout the essay writing process for awards submissions. As a result, she found that students were not as focused on tasks or deadlines and that she was doing a lot of the work herself.

> I found that I would try to be more prompting with them, to give them the thing that I would like their answer to be. I might know what the answer is, and I want to see their thought process to get there. At some point, I just realized that the students stopped learning when I give them the answer. I realized that they weren't doing the work on their own [...] So I had to take that step back because they weren't taking initiative, and that was the only way that they were able to learn.

As a new mentor, Brinn struggled to release creative control and move beyond step one of her team's mentoring process (Figure 4.1) of "you do, while student assists." Brinn realized that while the projects on the robotics team were being completed, the students were not learning anything about the process, and the projects were being completed poorly. "My mentorship wasn't working for the kids, and it wasn't working for me as a human being." Brinn also was not as fulfilled by her mentorship style, and she felt herself burning out from choosing to direct students so closely in the mentorship process. After stepping back, students started taking more initiative and having a higher sense of ownership over their work on the team, reflecting her team's number one teaching philosophy (Figure 4.1). Though Brinn verbally described her process as "stepping back," her team's handbook also defines this process as the highest degree of mentorship: students do, while mentors watch.

Just like when she first started mentoring, Brinn has found new mentors on the team, sometimes struggling to apply the team's teaching philosophy by reading about it alone, particularly in being hands-off in mentorship. Though mentors are experienced in their particular field, Brinn's team prioritizes the opportunity for students to maintain agency in decision-making to grow and reinforce this philosophy through hands-on training of new mentors. In addition to mentoring students on projects, Brinn supports newer mentors in becoming comfortable with teaching students and supporting her team in allowing students to maintain ownership over their project's direction, timelines, and construction.

Figure 4.1

Brinn's Artifact: Mentor Handbook Team Philosophy

Teaching Philosophy & Creative Control

1. The team is NOT about what's best for the robot or best for mentors, but what's best for the students. As such, Mentors should apply a hands-off policy as much as possible, except for demonstration, assisting or safety reasons.

2. The students do the work. This is their opportunity to learn and grow. The students do the programming, research, problem solving, and building. Mentors can help them find the answers; explain options or alternative approaches, as appropriate to each student's abilities, while challenging their capabilities and expanding their experience. Mentors should try to not provide complete answers, or make all strategic decisions.

3. Mentors apply the proper spirit of FRC, not to interfere with the team's solutions. Creations, inventions, and ideas, come from all the team members. Mentors are there to guide the students through the process of building the robot that the students have conceived and designed.

4. The job of a mentor is to build the students and let the students build the robot. The four steps of mentoring are: you do (and explain) while the student watches, you do while student assists, they do while you assist, they do while you watch. It is the job of the mentor to determine where each student is on the path and move him or her along this path.

5. Students develop an appreciation for engineering by working hands-on and side-by-side with professional engineer mentors. All hands are on the robot together, and all ideas are heard and debated as a team.

Brinn's team handbook defines different types of mentors to assist with mentor training and retention, highlighting varied expectations for adults on the team. In their first season on the team, new mentors are assigned as "Associate Mentors," as described in Figure 4.2. Once joining the team, Associate Mentors are introduced to the team's Mentoring Philosophy (Figure 4.1) and shadow Lead Mentors (Figure 4.3), who demonstrate how to apply the team's mentorship practices over at least twelve months. In their first season, Associate Mentors are not assigned to lead projects or subteams unless they offer to take on responsibility but spend time learning about team mentorship practices and constructing artifacts of mentorship. After demonstrating an understanding of the team's culture and mentorship philosophy, Associate Mentors are invited to support the team as a Lead Mentor (Figure 4.3). As a Lead Mentor herself, Brinn helps the team by recruiting new mentors for specific opportunities and annually leads the team's awards applications.

Figure 4.2

Brinn's Artifact: Mentor Handbook Associate Mentors

Associate Mentors

Some mentors cannot make the time commitment of Lead Mentors. Regularly involved mentors with identified team roles or projects to manage are associate mentors. Examples of associate mentors might be a programmer who holds periodic training sessions, a machinist who provides scheduled safety certification and skills training on power tools or a parent who helps with shop organization, fundraising or event scheduling. An associate mentor's involvement might be a few hours every one or two weeks (more during build season). Parents of students are strongly encouraged to become associate mentors. Associate mentors have full responsibility for their selected role or project but are requested to defer to student leaders, Lead Mentors and faculty advisors on matters of team policy, budget, and strategy decisions.

Figure 4.3

Brinn's Artifact: Mentor Handbook Lead Mentors

Lead Mentors

Lead Mentors are extensively involved in the planning and overall operation of the team on a regular basis. They are active participants in the decision-making process for team operations. Lead Mentors have extensive responsibilities for an area of team activity including supervision of students and leading sub-teams. Lead Mentors are expected to have participated in at least one year as associate mentors in order to learn about the team and school policies. A Lead Mentor must be present during open shop periods. Lead Mentors are expected to travel to major events and competitions.

As an experienced mentor, Brinn adapted her style of directing students step-by-step to offering mentorship when students ask for support. Though she learned about *FIRST* as a student in high school, Brinn learned about effective mentorship tactics by observing fellow mentors on her team as a new mentor in 2013. As a team, Brinn and her fellow experienced mentors designed a mentorship handbook outlining mentors' expectations, types of tasks, and the team's mentorship philosophy. As mentors join the team, they learn about the application of mentorship in the context of the team and engage in extended inquiry processes as an Associate Mentor while learning about the practice of mentorship. Though supported by a handbook that outlines mentorship expectations on the team, new mentors often require hands-on training from more experienced mentors, especially focusing on practices that allow students to maintain ownership over their projects.

4.2.3.2 Amelia: Varied Team Structures

> I don't think you can mentor without being influenced by the way you interact with the world as a person. For mentors, it’s challenging because, a lot of times, they don't necessarily know what they want out of mentoring.

As a 28-year-old Lead Mentor, Amelia learned about *FIRST* after high school through her job, where she began volunteering at events before learning about mentorship. Outside of mentoring, Amelia is an Engineering Product Manager and an FRC FTA, where she travels around North America to support FRC events. Though she had mentored various robotics summer camps in the past before *FIRST*, Amelia joined her local FRC team as a mentor in 2017, where she spent more than 50 hours a month mentoring the team as a Lead Mentor until she relocated to Ontario in 2020. In the 2021-2022 season, Amelia began mentoring another FRC team near her, and she spent 20-50 hours a month mentoring as a Lead Mentor, supporting her team continually throughout the 2021-2022 season. On her pre-survey questionnaire, Amelia rated her mentorship expertise as ⅗, commenting that she has been “mentoring for several years in different roles.” As a mentor, Amelia found that the communication skills she learned through her MBA and in her day-to-day job allowed her to communicate with students interpersonally more effectively. Amelia noticed that conflict resolution, communication, and clear expectations are fundamental in training new mentors and working 1:1 with students.

During her interview, Amelia reflected on how she learned to mentor, sharing that “[When I first started mentoring] in 2017, I was two years out of college. I only knew vaguely more than these high schoolers did and didn't know how to deal with interpersonal conflict." Amelia reflected further on how she learned about FRC mentorship, sharing that she shadowed her team's Lead Mentor for 12 months after joining her team as a volunteer. As only four adult mentors supported more than 50 students annually, Amelia's team had a clearly defined student leadership structure emphasizing youth-led projects. Mentors on the team focused on helping students schedule and manage the team's safety and supported students in technical skills transfer when directly asked. Amelia described her team as "not motivated by competitive success," sharing that they typically ranked low competitively at events. Instead, the students on the team celebrated individuality and inclusive culture, where students had a safe space to express themselves and learn about STEM. Amelia observed how her Lead Mentor taught students on the team, sharing that "she founded the team, and she was an excellent resource to watch to see how she interacted with the students." Amelia remembered how impressed she was by how the Lead Mentor asked leading questions and would allow students to "chase down a rabbit hole" as they thought about competitive strategy. As a team, Amelia described mentorship as students "leading the charge, and [mentors] making sure that the charge stays within these tracks."

As a mentor of her team for several years, Amelia eventually took over the role of Lead Mentor, where she trained new mentors and led administrative duties. In her interview, Amelia shared that her approach as a Lead Mentor focuses more on how engaged mentors are in the team and team sustainability rather than directing student projects. "The big thing with mentor engagement is helping people feel like they are contributing." As new mentors joined, Amelia would share information about her mentorship practices with them, having conversations about encouraging students to speak up and how to have constructive conversations with youth. As a Lead Mentor, Amelia especially learned about gathering information to aid in conflict resolution to “be thoughtful in asking questions to understand a situation.” She found that if she asked a question and was met with silence, the language may be too complex for a student's comprehension. Amelia shared that frequently, “just rewriting the question can get you far,” rather than being frustrated that a student is unresponsive.

After moving to Ontario in 2020, Amelia immediately took on another Lead Mentor role with her local team through the 2021-2022 season. The team was affiliated with a public high school, which served 705 students in the 2021-2022 school year (Ontario Ministry of Education, 2023). Ten percent of the student population lived in low-income households, while 6% of the student body’s parents did not have a post-secondary certification (Ontario Ministry of Education, 2023). Further, 5% of the students at the school spoke a first language other than English, which was significantly lower than the Ontario average of 25.2% (Ontario Ministry of Education, 2023). In contrast to her first team’s student-led model, the team she joined in Ontario had many mentors. Instead of asking leading questions to students, the existing mentors on her new team took a more direct approach, asking students, “Who is not doing a task?” and then assigning a job to do. In her first month on her new team, Amelia learned about the team's culture by observing how mentors interacted with students in person and on the team's virtual slack channel.

Amelia’s team was significantly affected by continued gathering restrictions due to COVID-19 during the 2021-2022 season, where they often ran team meetings online. As the team’s Lead Mentor, Amelia managed communication with mentors, students, and parents, holding a more administrative role than her previous team due to their virtual meeting limitations. While Amelia was motivated to support FRC and students through mentorship, she struggled to enjoy mentorship remotely, sharing that virtual meetings were ineffective at maintaining student engagement in STEM.

> It is very demoralizing when parents are angry at you for stuff you have no control over. I had a parent be angry at me [that] we couldn't hold meetings in January because it was illegal to hold meetings in January. They said: “You're really letting the kids down,” and I said: “This is deeply upsetting to me. I understand that more virtual [youth programs] is not what students want now, but it's the best we can do.”

While she acknowledged that parents expressed disappointment and anger in the lack of availability for their children to participate in extracurricular activities, Amelia felt demotivated, burned out, and personally at fault for her inability to host meetings with her team. Amelia’s fellow mentors also struggled with applying mentorship throughout their virtual meetings, often speaking to students to instruct them on designing and building the team’s robot. Concluding her interview, Amelia shared that she missed the student-led culture of her old team and hoped to engage more with teaching students how to build robots rather than administrative paperwork that dominated her season.

> Coming out of this year, I have a better idea of what I find rewarding about mentoring [and] of how to build a goal [personally]. […] For me, there is a certain kind of team that I am well equipped to be effective as a mentor. [...] I plan to find that kind of team locally.

In her role as a Lead Mentor on two separate teams, Amelia reflected on the importance of team culture and the impact of community support on a mentor's motivation to volunteer. As a new mentor who learned about *FIRST* through her workplace in 2017, Amelia began her mentorship with *FIRST* as a mentor who was confident in her communication skills. After shadowing her team's Lead Mentor, Amelia gained more confidence in developing her interpersonal skills, including conflict resolution. Moving to train mentors on her team, Amelia observed the importance of positive feedback on her fellow volunteer's motivation to mentor. After moving to Ontario in 2020 and taking on a Lead Mentor position to an existing team, Amelia noted a difference in approach to how mentors took the initiative and assigned tasks on the team, which she attributed in part to the pressure to perform competitively, as well as the loosely defined leadership structure on the team. As a result of continued COVID-19 gathering restrictions, Amelia's team met online during the 2021-2022 season, and Amelia noted a lack of student engagement resulting from virtual meetings. As a Lead Mentor, Amelia felt demotivated by her team's extended community, especially by how disappointed parents of her team's students were by the inability to meet safely in person. After experiencing the differences in team culture in the application of mentorship, Amelia committed to finding another team that she is effective at mentoring in the 2022-2023 season.

4.2.3.3 Kamal: Defining Success as a Mentor

> It's not just the technical knowledge you're imparting [as a mentor], it's just being there as a person and asking how [the students] are or just being supported is much bigger than you realize […] It's a whole other avenue of things for me to learn.

As a 24-year-old *FIRST* alumnus, Kamal served as a resource in the *FIRST* community, advising several teams as a mentor since graduating high school in 2015. As a high school student, Kamal regularly led small projects among his peers, which helped him naturally transition from an FRC student to a mentor. Outside of FRC mentorship, Kamal worked as a software developer and volunteered as an FRC FTA, the most senior technical volunteer position at FRC events. Kamal started mentoring with a clear goal: to teach the next generation of kids and give them the same opportunity he had. In the 2021-2022 season, Kamal mentored teams less than 10 hours per month; instead, he virtually connected with several teams as a technical resource. Rather than supporting a single team, Kamal said, "I'd like to help as many people as possible."

On his pre-study questionnaire, Kamal self-rated his mentorship experience as ⅘, commenting that he has "multiple years mentoring, helped with some admin tasks [on the team, and I] know what it takes to build a robot and compete [at events]." Though Kamal self-rated his mentorship experience highly and demonstrated both technical and non-technical mentorship experience, when reflecting on his mentorship practices during his interview, Kamal first shared that "I still wouldn't say I know how to mentor, you know? There's no real way to do it." When he first learned to mentor, Kamal dedicated more time to a single team, consistently teaching the same group of students over 12 months.

While Kamal is experienced with the mentorship of technical and non-technical subjects, he often led projects such as programming the team's robot and building the electrical subsystems with students. As a mentor of several teams, Kamal found that his mentorship was more effective on a team where he "filled a hole. I wasn't doubling or tripling up as a mentor. I was just adding on." Though he was experienced with technically building robots, he found that students were more confident on teams where students did the most work possible and were the leaders of their projects, for example, instead of mentors designing and machining robots when they only reviewed code or suggested research topics. As a *FIRST* Alumnus and event volunteer, Kamal was already familiar with technical subsystems to support students with strategy and quick troubleshooting.

> There was a person helping them who had never really done *FIRST*. They weren't ever part of a team, they were a person who did programming and came into the system and learned. But they missed some of the nuances and keeping up with things and so the Lead Mentor was looking for someone who knows the in's and out's, and I had been a CSA.

Though he was comfortable mentoring students about technical subsystems more quickly than mentors with no *FIRST* experience, Kamal learned about general mentorship after several years of supporting FRC teams. As part of his interview, Kamal submitted a personal journal he created about his mentorship methodology for technical subsystems (Figure 4.4).

In his journal entry, Kamal explained that his methodology as a mentor is for more experienced students to mentor new team members, providing his support as needed. Though students were not formally assigned a "level of experience," Kamal kept track of student's comfort with technical tasks and adjusted his mentorship approach accordingly for each student. Notably, Kamal approaches his mentorship from a community perspective, engaging with tutorials made by other *FIRST* teams. Throughout his interview, Kamal often defined his application of mentorship using words like "guiding" and "instructing" rather than "showing" and "doing." In his interview, Kamal shared that he was motivated by seeing teams work together:

> The type of team where I see a robot is broken, and three students suddenly fix it while the mentor is just there for support. I love it when a team knows the problem they're trying to work towards, and you can help them, and the robot works by the end of the day. I want to put that philosophy into as many things as possible with as many people as possible that I know.

Figure 4.4

Kamal's Artifact: Mentoring Methodology

Mentoring Methodology:

- Trickle down mentoring, have more experienced students run workshops to teach the newer ones. For example, making a wiring tutorial, or explaining the control system of the robot.
- For programming, there are 3 stages of students that I would mentally group:
    - First
        - Brand new, has little to no programming experience.
        - With these students, I would try and do programming lessons, and guide them towards online lessons.
    - Second
        - Students with programming experience, but not robot coding.
        - With these students, I have them look at previous year's code and WPILib to get a feel for how robot code works.
    - Third
        - Experienced students who know robot code.
        - With these students, the goal is to push the boundaries, i.e. learn motion profiling, camera vision, etc.
        - This is done through online documentation, and looking at tutorials that other teams have made.

Kamal described success as a mentor as being empowered with the knowledge to build the type of robot they want. Importantly, Kamal did not define success as a mentor to be associated with the team's competitive success. Though competitive success was intrinsically motivating to Kamal as a high school participant, he noted that as a graduate, the competitive success of his team has no impact on his academic understanding in post-secondary or his job performance as a software developer. As a mentor, Kamal tells his students that "not winning isn't a failure. Not learning is a failure."

As a *FIRST* alumnus, Kamal chose to dedicate his time to mentoring many teams in the 2021-2022 FRC season. Kamal shared his mentorship methodology by sharing a personal journal entry outlining how he trains students about programming during build season. Though he was more comfortable with FRC-specific control systems than mentors new to *FIRST,* Kamal experienced no advantage in applying mentorship philosophies and non-technical projects. Kamal described his ideal mentor experience as one where he is filling a specific need on the team instead of duplicating the tasks of other mentors. Though he was personally motivated by competitive success as a high school participant, Kamal experienced no impact on a team's competitive success after graduating high school. As a mentor, Kamal makes every effort to regularly share that students are successful by learning rather than winning.

4.3 Building an FRC Community

This study also explored how participants design and develop a sense of community within a youth program, focusing on equity, diversity, and inclusion (EDI). Two emergent themes surrounded participants' descriptions of identity and belonging within *FIRST* (4.3.1) and mentorship practices that engaged with equity, diversity, and inclusion (4.3.2).

4.3.1 Identity & Belonging

During interviews, all participants were asked: "What elements of your identity influence your mentorship?" (Appendix D) that probed their identity and feelings of belonging as an FRC mentor. Throughout the interviews, half of the participants expressed having at least one negative experience that made them feel that they did not belong as an FRC mentor, which they perceived to be heavily influenced by their gender and sexuality, age, and physical and invisible disabilities. When considering barriers to accessing FRC programs as a mentor, three participants described barriers such as the cost of associated travel and availability to take time off work. All participants expressed program-based barriers influencing the ability to develop team culture, such as lack of consistent mentors, time required to mentor students, and inability to access facilities. Despite facing personal economic, mental health, and societal access-related barriers, no participant discussed sharing their housing status, number of jobs, and reliance on public transportation with students or fellow mentors unless explicitly asked. Importantly, participants did not share words associated with feeling ashamed of the barriers they faced as mentors; instead, they saw little importance in how their background should (or could) be shared with students on the team unless they were to build empathy within a mentor-mentee relationship.

When considering program-level inclusion and feelings of belonging for students and mentors, all participants unanimously agreed that *FIRST*'s focus on the core values of inclusion was authentically inclusive rather than "checking a box," which was unique compared to other youth STEM programs such as VEX or Science Olympiad. Three participants mentored teams at public schools in Ontario, three participants mentored public Catholic schools, one mentor supported exclusively Indigenous students, and one mentor volunteered at a community team that was unaffiliated with any schools. As a program, more than half of the participants either witnessed the impact of financial barriers on fellow mentors or personally experienced financial barriers due to lived experiences, which included influences of the increased cost of travel, time to commute, and cost of eating due to the FRC programs required time commitments.

4.3.2 Engaging with EDI

In response to the pre-study questionnaire (Appendix C) that asked participants about their previous experience with mentorship training, mentors responded with varying degrees of previous experience. All participants completed some form of mentorship training provided by *FIRST,* which included slide-based asynchronous modules defining broad terms such as equity, diversity, and inclusion. Outside of *FIRST*'s asynchronous modules, two participants completed formal training in the form of a Bachelor of Education (Cade) and certified professional development for *FIRST* mentorship (Claire). Outside of FRC, six participants had experience as mentors for other robotics programs such as Vex (Claire and Kamal), Science Olympics (Cade), and robotics camps or workshops (Amelia, Brinn and Jace Hammervik). Three participants (Amelia, Claire and Cade) also engaged with youth inclusion training as volunteers for other OST programs such as Pony Club and Girl Guides.

When reflecting on how they learned about EDI, three mentors shared that *FIRST*'s EDI training was informative but did not provide authentic engagement practices. All participants described the importance of including diverse mentors and students on their team; however, only two had experience designing student workshops aimed at inclusive practices, and one participant also designed print resources for the *FIRST* community. During interviews, all participants were asked questions (Appendix D) that probed their mentorship approaches and the influence of socio-cultural factors, gender identities, and disabilities of fellow students and mentors within FRC. Four participants described having "no explicit tactic to develop inclusive communities." Instead, they described their mentorship approach as individualized to each student. In their interviews, half of the participants observed the influence of high program operation costs on students' ability to participate (Amelia, Cade, Jace Hammervik, Megan). Generally, participants did not reflect on the influence of socio-cultural factors on student participation, except for Cade's in-depth articulation of the influences of "dominant Western cultures" on Indigenous students when participating in STEM programs. Three of the study's participants described moments where, upon reflection, they felt their EDI was "inauthentic," such as recruiting one to two students exclusively for cultural diversity, which they acknowledged throughout their interview was not supportive (5.3.2). Five participants shared that when supporting diverse students, they were "afraid to make a mistake" and felt it was "inappropriate to ask for clarification from students."

4.3.3 Case Studies

The cases presented in this section illustrate how participants generate a sense of community for students and mentors within their robotics teams during the 2021-2022 FRC season. Cade repeatedly expressed his desire to remain invisible as a Lead Mentor and celebrate Indigenous FRC students' courage by highlighting their experiences of systemic racism and barriers to access to resources. As a mentor of two FRC teams, Megan reflected on socioeconomic factors that influence team culture and the personal impact of her volunteerism throughout her gender transition. Finally, Jace Hammervik shared their experience as a new mentor, highlighting the influence of housing status, health, and level of education on their integration into a team culture.

4.3.3.1 Cade: Remaining an Invisible Ally

> My basic thing is nobody needs another middle-aged white man talking in the room. So, as much as possible, my role is to make sure that First Nations youth are doing the talking. So my identity is to be invisible.

As a math and science teacher for 22 years at a school in an Unceded First Nation in Northern Ontario, Cade described himself as an "outsider." Having grown up in Waterloo, Ontario, Cade completed his Bachelor of Science, Bachelor of Education, and Master of Philosophy before accepting a position as a math and science teacher at a high school with a population of 120-250 annual students. Outside of robotics, Cade was experienced with wilderness camping and valued getting outside skiing and on the water to keep healthy. As a mentor, Cade is motivated to support First Nations youth in courageously pushing back against "a history of exclusion that is very deep […] where everyone says that your land doesn't matter, your voice doesn't matter, your children don't matter." The important part of the *FIRST* program for Cade is to allow students to "open [their] imagination of self in ways that [they] wouldn't have been able to imagine otherwise."

Working as a certified teacher in Ontario, Cade donated his time for 14 years outside of work to run a Science Olympiad team before transitioning to volunteer as an FRC Lead Mentor in 2015. On his pre-study questionnaire, Cade donated the highest monthly time as a mentor, spending 50-100 hours each month in the 2021-2022 FRC season with his team. When describing the organization of his rural team, Cade noted that he struggled to recruit and retain other local mentors, sharing that other FRC teams have at least "six or seven mentors, most of them have somebody with engineering, computer science, and business backgrounds" in addition to having connections to "parents who are connected to industry and sponsorship." As a Lead Mentor, Cade has supported his team and community outside of the traditional expectations of a volunteer, having attended the funerals of more than a dozen students. Despite financial, emotional, and resource challenges, Cade's community has supported the students in other ways. Cade's team has presented their work to the Chief and Council, sharing stories of their experience in FRC with their tribe:

> [The k]ids are never left behind. [In the] first and second year [of the team's operation], one of the cafes in town raffled a car for us to cover our expenses. The Hawk Shop has run Chase the Ace for us. So, everyone steps up.

To foster the *FIRST* community, Cade drives with his students two to five hours south for day-long robot build sessions and participates in presenting conference sessions about community development initiatives that his students are working on. Since the team's inception, Cade has encouraged students to celebrate their identity and have the courage to share that with other groups at FRC events. When considering what developing an inclusive culture means to his mentorship, Cade described that

> First Nations cultures don't have the same sexism, racism, and homophobia that is a big part of Western culture. That's still very much a part of our […] community today. The students have also grown up with each other. They know each other from nursery school. There's a depth of acceptance of each other, and people's space for each other is remarkable. That carries through to the team.

In their first season, Cade's team offset startup costs by building their robot from "cast-offs from the dump." Cade described the unique atmosphere at *FIRST* events, where "the kids [on my team] have never been made to feel second rate […] even though they might expect to." Cade brought attention to the courage of his students to participate in STEM programming, sharing that

> The kids have seen the programming that comes and goes [… They're] used to that ebb and flow here. To have something consistent year after year with an authentic depth of commitment and interest. Something that is not just a Diversity, Equity and Inclusion as a checkmark.

In the video artifact that Cade submitted, his team reminisced about the success of their first event in 2015. Cade contrasted his five FRC students with other teams participating in the event, sharing that the students on his team were intimidated by busloads of students in matching uniforms. In contrast, his team borrowed shirts from the school's volleyball team and drove together in an old van. Cade further contextualized the systemic barriers his students have pushed against to participate in STEM programming. When travelling to and from FRC events, Cade described how his students have faced "obvious racism," where the kids get followed by security in stores and "are hassled because they're Indigenous."

Despite the students' perceived differences and racism when travelling to an event, the team performed well in their first competition. In his submitted artifact, Cade's team shared that they won three rookie awards in their first competition season, which "proved they could stick with the big dogs." Further, their principal shared that "there's no other program that brings together the diversities within our high school than *FIRST* does." Since 2015, 50% of the students have been women, with many leadership positions being filled by women. Cade reflected on exclusive student positions on the team (such as the robot's driver) being held by transgender students, sharing that "it's not saying: okay, one member of the driver team has to be this and the other has to be that." Instead, they have designed a consistently inclusive space that has attracted diverse students to STEM.

Cade's identity to "be invisible" as a mentor allowed the strengths of his students' culture to build an inclusive youth STEM program that students can rely on despite a history of "inconsistent programming" for First Nations youth. Throughout his interview, Cade contextualized his students' experience with "obvious racism" and "a history of exclusion" by sharing stories of their courage to participate on the team. Compared to other youth STEM programs Cade has run, he found *FIRST* to foster the development of authentic, inclusive spaces, where First Nations communities were not included just to be "checking a box." Though Cade faced mentor retention and team resourcing barriers, his team demonstrated that competitive success at an FRC event is not dictated by a team's available funding or the number of mentors present.

4.3.3.2 Megan: Spaces to Share Identity

> I just really enjoy watching these kids grow […] They're just so young that you see that change, which was amazing focusing on how to make these kids better human beings in general, not good at robots.

As a 24-year-old *FIRST* Alumna with her high school diploma, Megan brought a wealth of technical and organizational experience to her FRC mentorship. In her five years of mentoring since graduating high school, Megan volunteered with a different FRC team each year to best support her work-life balance. Outside of mentoring, Megan worked two jobs and commuted via transit to volunteer as an FRC Lead Robot Inspector. As the 2021-2022 FRC season saw a return of in-person events after COVID-19 restrictions, Megan was especially motivated to represent *FIRST* "as an openly visible trans person to finally volunteer […] and do mentorship that way." For Megan, the vital part of FRC mentorship is to create an environment where students see themselves represented and feel ownership over their work.

As a child, Megan was always naturally interested in STEM and robotics, choosing to join her school's FRC team in high school. On the team as a student, Megan was highly motivated to build a successful robot, reflecting that

> As a team, we were really burnt out and incredibly angry at each other. I don't think I've ever been more stressed in my life than in that year, and our marks were suffering for it. So I really wish someone had stopped me.

Though Megan had some incredibly influential mentors throughout her high school experience, she still "dreamed of what it would be like if I had a good mentor" who would support the team's technical performance and help her set boundaries between robotics and schoolwork. As an adult mentor, Megan recognized that she does not "personally have the resources to run a team on my own." She also acknowledged personal barriers to mentorship, such as the time to commute to a meeting and the impact on her health, sharing that due to the cost of food, in her first few years as a mentor, "oftentimes I was not eating at all."

On her pre-study questionnaire, Megan donated fewer than 10 hours a month as an FRC mentor during the 2021-2022 season, sharing that she was "in between teams." She self-described her level of experience with FRC mentorship as ⅗, writing that:

> I believe I've mentored multiple roles, some more technical than others. I believe this expertise gives me some level of expertise, but I'm always looking to learn more.

In addition to mentorship, Megan annually volunteered at three events as an FRC Lead Robot Inspector (LRI). As an LRI, Megan must pass a technical certification quiz annually and manage a team of five to ten volunteers to mentor FRC teams over three-day competitions. Though she has mentored four FRC teams since 2015, Megan primarily compared and contrasted her mentorship application for two teams during her interview. For the study, these teams are referred to under pseudonyms as Team Green and Team Blue. Table 4.3 lists a summary of the government of Ontario Ministry of

Education's reported enrollment at schools for Team Green and Team Blue in the 2021-2022 school year (Ontario Ministry of Education, 2023).

Table 4.3

Summary of 2021-2022 "Team Green" & "Team Blue" Student Recruitment Pool

	Province of Ontario	**Team Green**	**Team Blue**
Type of high school	N/A	Catholic	Public
Enrolment 2021-2022	N/A	2180	695
% of students living in lower-income households	17.7	14	21
% of students whose parents do not have a certificate, diploma, or degree	6.3	6	12
% of students whose first language is not English	25.2	19	46

Megan first mentored Team Green as a recent high school graduate one year out of high school. She described Team Green as a strong team with ample mentor and parental support that contributed to the team's competitive success. The team was affiliated with a public Catholic high school in a suburban area, with more than 2000 students enrolled annually (Table 4.3). As the team had many experienced mentors, Megan learned about FRC mentorship by observing her peers, which she found fascinating. As a mentor, she focused on teaching students how to use tools safely and "dialling down the level of skills to teach the kids." On the team, Megan felt included by her fellow mentors. She especially loved that the mentors had their social group that was “a nice place to hang out with people my age.” Parents of students on the team frequently brought homemade meals, going out to pick up parts for the team’s robot and grabbing coffee for the mentors. When reflecting on her identity, Megan described her time as a mentor on Team Green as

> The first time that I saw a trans person mentoring, which I thought was really cool because it’s hard to know if that’s something that you’re allowed to do. I had people in my life say: “They’re never going to let you volunteer or mentor students again.”

Though Megan was “a little out to [her] students,” she shared in her interview that sometimes mentoring could be easier if you’re not open with that identity. As she reflected on EDI within Team Green, Megan described the team as a place that was a safe space where “there were always a lot of kids who were experimenting with gender.”

Following her season with Team Green, Megan was asked to support Team Blue as a Lead Mentor. In contrast to the community of mentors she described on Team Green, Team Blue’s students were “fiercely independent,” having only one or two other mentors besides Megan’s support. Team Blue was affiliated with a public high school, serving 795 students in the 2021-2022 school year (Table 4.4). The team was in a metropolitan downtown area where students take the subway and bike to school. On Team Blue, parents worked daily until 10 PM, and most families did not have a car to pick up materials for the team. The team only had access to facilities during the evenings after school, limiting students' in-person meeting hours. For most students on Team Blue, FRC competitions were the only opportunity to travel, experience different cultures, and meet people outside of their town during high school. Megan described her mentorship of Team Blue as

> A little more holistic because the kids were so independent and they were really competent. It was "How can we teach these kids to be somebody?" I had this really bright student, but she wasn't the best communicator, so I was thinking about how to teach her how to communicate ideas to the rest of the team in a way that everyone else would understand.

As a Lead Mentor, Megan was more directly involved with guiding students in their decision-making and process on the team. Megan found Team Blue to struggle to sustainably maintain consistent mentorship, even though she spent time recruiting and inviting new mentors to the group as a Lead Mentor. Partially due to a lack of available mentors, Team Blue approached FRC with a "student-led model," where students held leadership positions, trained newer members as near-peers, and made strategic decisions about the team's operations.

As a mentor, Megan fosters a culture of inclusivity by creating an environment where students feel comfortable and listened to. When considering her identity, Megan shared, "For me, being transgender, my robotics team was actually the first place I was openly out to." As a Lead Mentor, Megan aims to manage rapport between herself and her students, emphasizing that "you don't want them to feel scared to talk to you or that they can't talk back." On Team Blue, students chose to write an essay nominating Megan for the Woodie Flowers Award, which "recognizes mentors within the *FIRST* Robotics Competition who lead, inspire, and empower using excellent communication skills" (FIRST, 2022b). Megan describes the submission as personally meaningful: "It was the first document that I had [in my life to] use she/her pronouns in it." Having mentored multiple FRC teams, Megan has learned about the influence of community engagement in the success of a robotics team. Despite differences in community involvement between Team Green and Team Blue, Megan witnessed the impact of safety and inclusion on team culture from mentors sharing their gender identity as part of their youth mentorship practices. As a Mentor on Team Green, Megan looked up to fellow mentors who shared their identity as transgender with herself and the team. Despite being wrongly told by a parental figure that she would never be allowed to mentor youth after sharing her identity as a transgender female, Megan openly shared her identity with the *FIRST* community. As a mentor of Team Blue, Megan's mentorship practices were recognized by her students in an essay nomination, where they used Megan's she/her pronouns for the first time.

4.3.3.3 Jace Hammervik: Developing EDI Intentionally

> I left home at 17. I am still low-income. I was an at-risk youth. A lot of it was that I was around people who were struggling with a lot of things. Whether it be addiction, mental health, abuse, that kind of thing.

As a 21-year-old *FIRST* alumni, Jace Hammervik mentors their FRC team between working as a sales representative and taking their final high school credit for their diploma. As a mentor, Jace Hammervik relies on bus transit and carefully budgets volunteerism with *FIRST* due to financial strain. Jace Hammervik's team is a community-based team of 20 students from the surrounding area. During the 2021-2022 season, Jace Hammervik donated an average of 20-50 hours each month to their team as a volunteer. The team is unaffiliated with local schools, churches, or businesses. On their pre-study questionnaire, Jace Hammervik rated their experience with mentorship as ⅖, commenting that “I am still very new, as this is only my third season.” Throughout their interview, Jace Hammervik shared how they were learning to mentor students in technical areas on the team while mentoring their peers about developing a sense of community. Jace Hammervik openly spoke about the barriers they face as a mentor, stating that most people they look up to in *FIRST* have been involved in STEM.

> For me, it’s just not a pathway that’s available right now. I had to drop out of high school when I was younger, [meaning] that I have to go back and take six more credits on top of what I’m already trying to finish. It’s just not doable in my life right now.

During their interview, Jace Hammervik was excited to be completing their high school diploma, sharing that for them, the achievement would show people that “I didn't give up like you thought I was going to.”

During middle school, Jace Hammervik learned about *FIRST* as a participant on their FLL Challenge team. Entering as a high school student at a new school, Jace Hammervik was overwhelmed by the 100 student-robotics team, instead choosing to join the smaller community FRC team within their city. As a student, Jace Hammervik shared that “what drove me to participate was the teammates and the leadership.” As the first openly queer person on their FRC team, Jace Hammervik helped their team develop resources for 2SLGBTQI+ *FIRST* students. In grade 12, Jace Hammervik relied on their team as a support network, moving out of their family home. After graduating high school, Jace Hammervik was inspired to mentor their robotics team to continue to build a community where students feel safe.

After graduating high school, Jace Hammervik began to focus on both their mental and physical health, often requiring a cane or a wheelchair to aid in their mobility. Jace Hammervik described their experience navigating physical mobility as "being used to being forgotten in a lot of spaces. People forget that I walk a lot slower than them, or they'll forget that I need to be pushed down somewhere in a wheelchair." As a mentor, Jace Hammervik is learning more about the technical aspects of FRC by learning about machining from their fellow mentors. Though spaces that Jace Hammervik mentors in are inclusive, they sometimes feel left out, sharing that "I notice that I'm not able to stand in the build space and help with things."

When considering the design of FRC team culture, Jace Hammervik recommends that mentors are intentional about making a safe space accessible for students and their communities and acknowledging barriers they may face. "You absolutely do want that without tokenizing people. It's not about tokenizing. Naturally, you will get people from lots of groups who are marginalized and underrepresented in STEM." Jace Hammervik's team proactively curates resources such as mental health and wellness, community housing, financial aid, physical accessibility, and gender and sexuality resources for all students.

Additionally, mentors openly share how their identity uniquely positions themselves as mentors. Jace Hammervik has found that "showing them how they can relate to you is the best way to keep students engaged." For example, as a genderfluid mentor, Jace Hammervik has annually had several students privately come out to them while looking for resources to navigate their gender and sexuality. In contrast, other mentors on Jace Hammervik's team support have helped students in other areas. Jace Hammervik was careful to share that

> A key thing is making sure that your team is intersectional about it. The easiest way not to single someone out is to make sure that the resources and care that you have within your team and your team culture is intersectional. You're not making it just a safe space for one group of people.

Since Jace Hammervik joined their FRC team as a volunteer, fellow mentors have seen a shift in the team's culture. While Jace Hammervik attributes a lot of the culture change to their experience as a marginalized person, Jace Hammervik's mentors are also intentional about frequently participating in EDI training sessions within their community, such as *FIRST*'s online mentorship training (e.g. FIRST, 2021a). "EDI training isn't going to give you lived experience, but it's at least going to make you aware of things that you may not have otherwise have been aware of and otherwise not had a grip on." After completing training modules, Jace Hammervik's team mentors think, "How can we make this space for other groups to join?"

As a mentor, Jace Hammervik openly shares their experience with students, demonstrating the intersection of multiple aspects of their identity with their team. While Jace Hammervik described their commitment to mentoring as "not as much time as I would like to," they acknowledged personal barriers such as reliance on transit and accessibility barriers such as the inability to stand in the build space to teach students about technical tasks. As a mentor, Jace Hammervik has sought technical advice from fellow mentors while sharing resources about community development. When developing an inclusive space for students, Jace Hammervik has recommended that teams seek out EDI training for mentors and discuss how to create a safe space for communities.

4.4 Summary of Findings

This exploration into each participant's engagement with STEM mentorship and the design of inclusive practices has revealed several common findings relevant to educational applications and future research. They have been organized in the sections below based on the study's themes.

4.4.1 Engaging in STEM Mentorship

- Participants' most commonly held belief was that competitive success is not a metric of effective mentorship in FRC.
- Participants learned how to mentor FRC teams by observing and shadowing more experienced mentors for at least 12 months.
- When asked to describe their mentorship approach, no mentor used technical terminology such as "Pedagogy" or "Project-Based Learning"
- In submitted artifacts, participants expressed their mentorship practices using more formal language than in conversation.
- As mentors gained more experience with FRC, their educational approach transitioned from directive and controlling to guiding using leading questions.

4.4.2 Building an FRC Community

- Participants unanimously agreed that *FIRST*'s core values supported the development of authentic, inclusive practices for students and mentors in STEM.
- All mentors expressed the desire for more inclusive teams, but only three could articulate how they developed a culture of authentic inclusion.
- All participants experienced program-based barriers such as burnout, which influenced the quality of a team's inclusive environment for students and mentors.
- Half of the participants described at least one experience associated with their identity that made them feel like they did not belong as STEM mentors.
- Most participants experienced fear and hesitation associated with "getting it wrong" when learning to support diverse student needs.

5 Discussion

5.1 Overview

This study explored participants' experiences in educational robotics mentorship and how volunteers develop a sense of community within a youth robotics program. The following chapter will discuss the significance of the findings (4) described in the previous section. This study contributes to the continued development of research in educational robotics since the early 2000s (Anwar et al., 2019), particularly in youth STEM programs. Researcher's evaluation of the quality of PjBL youth programs (e.g. Aresi et al., 2020; Davis et al., 2021; Koomen et al., 2020) emphasizes the importance of volunteer training which models effective mentoring practices to new volunteers. Training for new mentors should include techniques which support the development of low-stakes, socially safe environments, and seek to support volunteer engagement through hands-on, project-based examples. Given the need for authentic EDI engagement in youth STEM programs (e.g. Kekelis et al., 2017; Powers et al., 2015), the research sought to investigate the impact of non-educators practical approaches on developing inclusive STEM spaces in a single study. The following research questions guided the study:

1. How have individual participants' mentorship approaches of grade 9-12 robotics teams evolved throughout their time as mentors?

2. What approaches do mentors use to develop a sense of community, particularly for underrepresented populations participating in grades 9-12 competitive robotics teams?

These questions were designed to illuminate how non-educators develop personal teaching practices and to shed light on how mentors conceptualize the principles of EDI in STEM youth programs. Using non-technical or informal language, participants could articulate their growth as informal educators throughout their mentorship practices, both in conversation and through written artifacts that defined mentorship methodologies. Further, participants articulated how they designed authentically inclusive environments for youth and mentors when considering EDI in STEM programs. The complete study results are available in Chapter Four.

The findings presented in this study are not intended to be generalized broadly to high school populations or other youth robotics leagues. Constructionist research aims to illuminate the varied subjective understandings individuals build from their experiences, which are heavily contextual to where they took place (Creswell, 2013; Merriam, 1988; Patton, 2002). As the study conditions took place in informal learning environments facilitated by non-educators, they cannot be compared 1:1 to formal educational robotics environments. The following sections analyze the results in greater depth and contextualize them to the existing literature on volunteer mentorship (5.2) and youth STEM programs (5.3). The chapter concludes (5.4) with a summary of both research questions, presented as a collective discussion of all participants' experiences.

5.2 Evolving STEM Mentorship

The prevalence and sustainability of youth mentorship programs in OST environments rely on the 15.65 million Americans (Americorps, 2023) and 2.9 million Canadians (Hahmann, 2021) who support youth programs annually as informal educators. OST mentorship programs such as FRC focus on the development of sustained mentor-mentee relationships over a minimum 24-week period (e.g. Dolenec et al., 2016; Yoel et al., 2020), mitigate commonly reported program operational barriers such as mentor training, volunteer recruitment, and mentor satisfaction (Aresi et al., 2020). Additionally, FRC teams who engage in sustained program mentorship year-round have a higher degree of communication and technical subject transfer between mentors and mentees (Dwivedi et al., 2021).

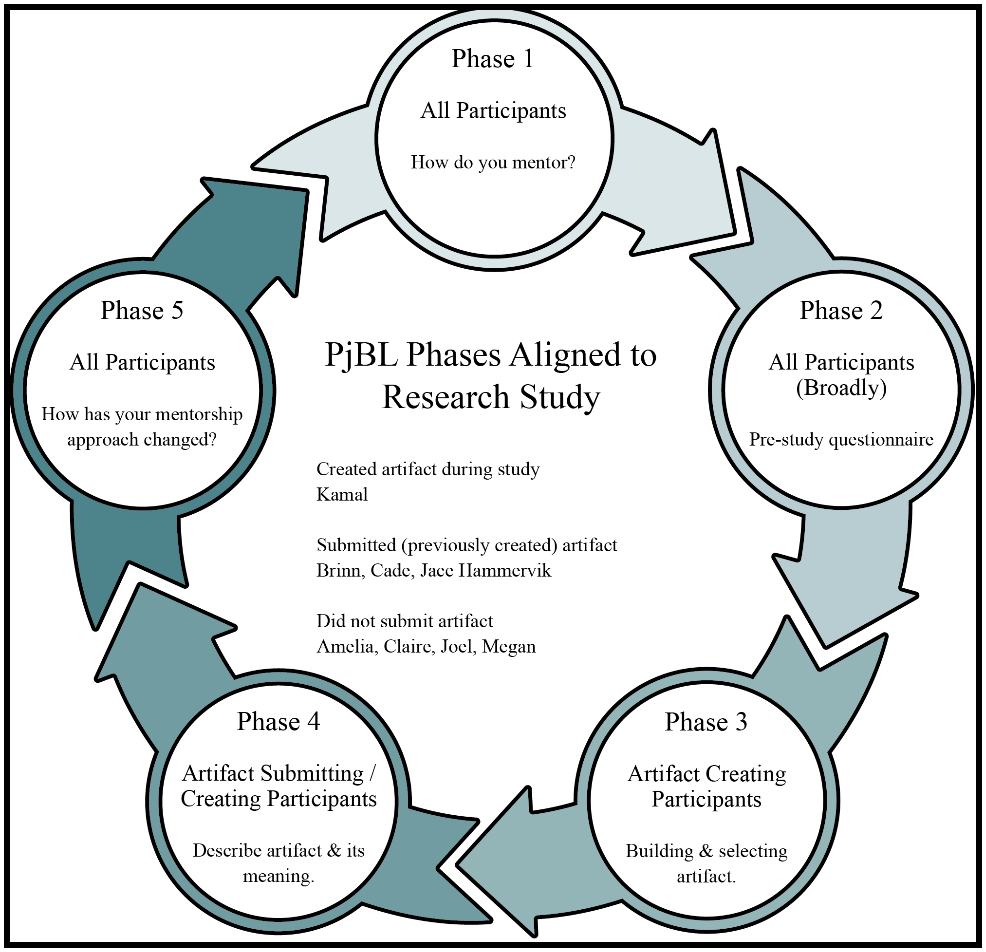
For highly technical subject-specific OST programs such as FRC, student participants are expected to have a more influential subject-skill transfer than generalized STEM programs (Burack et al., 2019; Ozis et al., 2018). Though the literature has suggested numerous additional participant outcomes, such as an increase in global competencies, workplace skills, and academic self-concept (e.g. Burack et al., 2019; Meschede et al., 2022; Yoel et al., 2020), youth programs rely on the recruitment and retention of volunteers for its program operation. For OST youth STEM programs such as FRC, emphasis on annual project-based learning challenges offers continued support to mentors in the form of curriculum guides and professional development, allowing them to focus on the development of socially safe informal communities for mentors and mentees to practice a common subject interest (Davis et al., 2021; Hennessy Elliott, 2020; Koomen et al., 2021; Verma, 2015). This study's first research objective was to investigate how volunteer educators describe the development of their youth mentorship practices. Three major themes emerged in the findings: (a) artifacts of mentorship (5.2.1), (b) how volunteers learned to mentor (5.2.2), and (c) the style of mentorship that volunteers use (5.2.3), including participants' descriptions of "ineffective" mentorship (5.2.3.1) and "effective" mentorship (5.2.3.2).

5.2.1 Artifacts of Mentorship

Throughout the study, participants engaged with several phases of PjBL as outlined by researchers as illustrated in Section 2.6.2 (Lee & Galdino, 2021). Expanding on existing literature and the framework described in Figure 2.1, the phases of project-based learning have been illustrated as they relate to the study's discussion (Figure 5.1).

Figure 5.1

Alignment of Project-Based Learning (PjBL) Phases to Study



Upon recruitment to the study, mentors were provided with a list of interview questions (Appendix D), which served as guiding questions (PjBL phase 1) such as: "How do you mentor FRC?" As an active member of the *FIRST* community, my role in the study was dual purpose, both as a researcher and a community expert presenting probing PjBL-based inquiry for participants (Bruner, 1961; Kokotsaki et al., 2016; Lee, 2018; Lee & Galdino, 2021). Due to the study's time constraints, participants were not asked to engage in planning or researching how to mentor FRC (PjBL phase 2). Instead, I provided a timeline to participants (Figure 3.1) and broadly scaffolded technical terminology relevant to their inquiry (Appendix B, Appendix E, Appendix F), such as "artifacts of mentorship." As an additional part of phase 2, participants documented any record of training they had participated in (both by *FIRST* and external training) during their pre-study questionnaire (Appendix C), which informed their experience with the guiding question. All participants were encouraged to construct their artifact of mentorship (Phase 3); however, only Kamal participated in the iterative and social process of responding to the driving question.

Along with Kamal, three additional mentors (Brinn, Cade, and Jace Hammervik) presented their artifact of mentorship (phase 4) during their 1:1 interview. Using artifacts as a vessel for communication allows participants to present their mentorship approaches through informal presentation, sharing their findings with me as a member of the *FIRST* community. Participants who presented artifacts during their interview demonstrated a thorough ability to present, reflect, and analyze their mentorship practice (FIRST, 2021a). The social presentation of a constructed artifact (Lee, 2018; Koomen et al., 2021; Wickliffe et al., 2020) allowed participating mentors (Brinn, Cade, Jace Hammervik, & Kamal) to actively re-direct their interviews to include deeper discussions on conceptually challenging topics such as instructional versus facilitating mentorship (Brinn & Kamal), tokenism (Jace Hammervik), and historic racism (Cade).

All eight participants reflected individually on their learning as a mentor (PjBL phase 5) through probing questions during their interviews. The use of mentorship artifacts as part of the discussion during interviews facilitated a greater depth of engagement with personal relevance and application of mentorship. After presenting his submitted video artifact (Table 3.4), Cade reflected that *FIRST* as an organization genuinely supported sharing stories of the First Nation's community that he lives in and that "making connections with other [local] teams in our first year" was essential to the sustainability of their team. Similarly, after producing his artifact of mentorship in the form of a journal entry (Figure 4.4), Kamal articulated his mentorship approach chronologically, describing a tiered approach to programming that pairs inexperienced students with more experienced peers. Though the four participants who chose not to submit an artifact of mentorship participated conceptually in PjBL's first and final phases through the natural progression of informal interviews, they exhibited a limited ability to describe their mentorship strategy using descriptive language cohesively. With no artifact to guide their discussion, some participants sometimes struggled to articulate in-depth concepts during their interviews. For example, Amelia described a critical approach to growth as a mentor to discuss with fellow experienced mentors how they might resolve conflict. Though she non-verbally exhibited cues such as sweeping hand gestures and confident facial expressions, Amelia resorted to non-descriptive filler phrases such as "I handled this XYZ way" as a storytelling technique when responding in depth to questions. Through probing follow-up questions, she deepened her description of her journey learning to mentor, asking trusted fellow mentors questions such as "Is there a way you would have handled this scenario differently?" Despite Kamal, Cade, and Amelia's mentorship practices aligned with previous literature documenting the importance of peer feedback on personal motivations to mentor and retention of volunteers (e.g.Aresi et al., 2020; McMorris et al., 2018; Powers et al., 2015), Amelia struggled to share evidence of her understanding of this abstract concept without the use of a constructed artifact (Papert, 1980; Psenka et al., 2017).

5.2.2 Learning to Mentor

Throughout the study, participants demonstrated limited conceptual usage of technical terms related to mentorship or pedagogy. For example, when sharing a digital copy of her artifacts over email for inclusion in the study, one participant captioned her work as: "Additional documents for the mentor thingy." When first asked: "How do you mentor?" (Table 4.2), no participant articulated a single strategy or approach to their mentorship facilitation, nor did they initially share any details about the effectiveness of training modules. Instead, industry-focused mentors like Amelia and Claire gained confidence in their mentorship by shadowing more experienced *FIRST* mentors and observing exemplary mentorship practices (Kekelis et al., 2017). Meanwhile, near-peer *FIRST* alumni described recent experiences as *FIRST* students, where they often learned how to mentor through trial and error with varied success (Powers et al., 2015). Finally, Cade shared that he did not believe there was a single approach to mentorship (Koomen et al., 2021) but followed with his strong belief in the strength of young people in solving global problems, especially First Nations youth.

FIRST's adoption of PjBL methodologies is evident in the production of annual project-based season themes (FIRST, 2022b), encouragement of facilitated mentorship (rather than instructional) based relationships between student and educator (FIRST, 2022a), and engagement with the concept of community members as expert advisors (Lee, 2018). Despite *FIRST*'s programs and training being “developed using a project-based learning pedagogy” (Simpson & Rodino, 2021), the informal educators who participated in the study demonstrated a limited ability to identify or describe PjBL as a framework or use pedagogical terms. Of the eight study participants, only two used the word “Project” frequently during their interviews. Cade broadly defined the development of a team's annual robot as a project culminating in students competing at the end of the season. Meanwhile, Brinn frequently used the word “Project” during her interview, which she used to describe both the production of the team's annual robot and other mentee-managed tasks on her FRC team, such as the research and presentation of the community service-based “Impact Award” (formerly the “Chairman's Award”). Despite Brinn's team “projects” containing the relevant phases of PjBL (asking meaningful questions, planning an investigative strategy, gathering information, presenting findings, and reflecting on learning) described by researchers (Blumenfeld et al., 1991; Helle et al., 2006; Lee, 2018; Sahin, 2013), she did not define an approach to mentorship using PjBL or any other framework during her interview. Instead, Brinn reflected on the differences in her mentoring approach from when she first started volunteering in 2013 to her mentorship in the 2021-2022 FRC season.

On the pre-study questionnaire, all participants indicated they had completed some form of mentor training, such as *FIRST*'s Professional Development (Simpson & Rodino, 2021) and *FIRST*'s EDI training (FIRST, 2021a). During their interviews, mentors described the importance of training for effective mentorship; however, they described limited satisfaction with completing workshop-based (*FIRST*'s professional development) and instructional-style (*FIRST*'s EDI) training. As with suggestions of previous literature (e.g. Franck & Donaldson, 2020; Kekelis et al., 2017), participants unanimously agreed that the presence of hands-on facilitation and curriculum links embedded in mentorship training are more successful than instructional or slide-based volunteer training. Further, long-term, 1:1 guidance from more experienced FRC mentors was described by each participant as an essential contributor to their initial retention as a volunteer in *FIRST,* similar to other youth STEM mentorship programs (e.g. Aresi et al., 2020; Davis et al., 2021; Franck & Donaldson, 2020; Powers et al., 2015).

Regarding training, participants' professional background (Teacher, Industry) and prior experience with the *FIRST* program as alumni (Near-Peer) influenced the support (subject-specific, facilitation-based, and relationship-building) they described as meaningful. Identifying as an industry mentor, Amelia exhibited high levels of confidence in up-to-date technical knowledge in the STEM field (Dwivedi et al., 2021; Kim et al., 2021; Franck & Donaldson, 2020) but initially required 1:1 guidance from the Lead Mentor who recruited her to learn about the nuances of effective mentorship for high school students (Jin, 2021). Similarly, as a near-peer mentor and event volunteer, Kamal was directly recruited by a local FRC team to train an industry-based software mentor who “did not understand the nuances of the control system” required in FRC competitions. As a recent graduate closer in age to FRC students, Kamal excelled at maintaining a socially safe informal environment through his mentorship (Kim et al., 2021), where he described one interaction with mentees:

> Kids like doing things they can see the immediate impact of. If you told [a mentee], “I need to do inventory [of robot parts],” they would respond with, “This is dumb.” As an Alum, I can say from experience, “If you do inventory now when you need the parts a week from now, they will all magically be there.”

Despite mentees using language like “this is dumb” to describe a lack of motivation in a task, they felt safe in their relationship with Kamal to share their feelings informally. In return, Kamal shared his experience and reasoning for requesting students take inventory of their mechanical parts for future team benefits while explaining the concept using equally informal language like parts: “magically being there.”

Outside of technical-based mentorship, as a near-peer mentor with high expectations of mentor-mentee relationship development and continual feedback from experienced mentors (McMorris et al., 2018), Jace Hammervik described *FIRST’s* slide-based virtual EDI training (FIRST, 2021a) as a “base point” that minimally educates a mentor about equity, diversity, and inclusion. Though Jace Hammervik qualified that the asynchronous training is an accessible starting point to inform mentors about terminology within EDI, as a mentor, they have personally observed “ableist” or “tokenistic” behaviour by well-meaning; however, unqualified mentors on their FRC team.

Finally, as an industry member with home-school experience, Claire initially described her experience with *FIRST*'s professional development workshop as having "taught me technical [programming & engineering] skills, but not interpersonal skills." When probed further, Claire shared that as an experienced mentor, she found that the most meaningful training she had ever received was 1:1 support from more experienced mentors. Despite her initial reflection that *FIRST*'s PD lacked training in interpersonal skills, Claire elaborated that participating in hands-on offerings boosted her confidence from "I can't learn to program" to feeling more manageable and satisfied as a volunteer. Further, as a Lead Mentor of her team, Claire exhibited confidence in age-appropriate facilitation approaches (Center for Youth and Communities, 2011; Koomen et al., 2021; Cicchinelli & Pammer-Schindler, 2022; Powers et al., 2015) but described benefits from subject-specific knowledge such as programming and engineering (Dwivedi et al., 2019; Franck & Donaldson, 2020; Jin, 2021; Kekelis et al., 2017).

5.2.3 From Instructing to Facilitating

As suggested in previous literature (Davis et al., 2021; Hennessy Elliott, 2020; Verma, 2015), FRC mentorship exists as multiple communities of practice (Figure 5.2):

- The entire *FIRST* program (All *FIRST* teams K-12 globally)
  - Practice: Engaging in community service, educational events, & PjBL challenges for K-12.
- The *FIRST* Robotics Competition (All FRC teams globally)

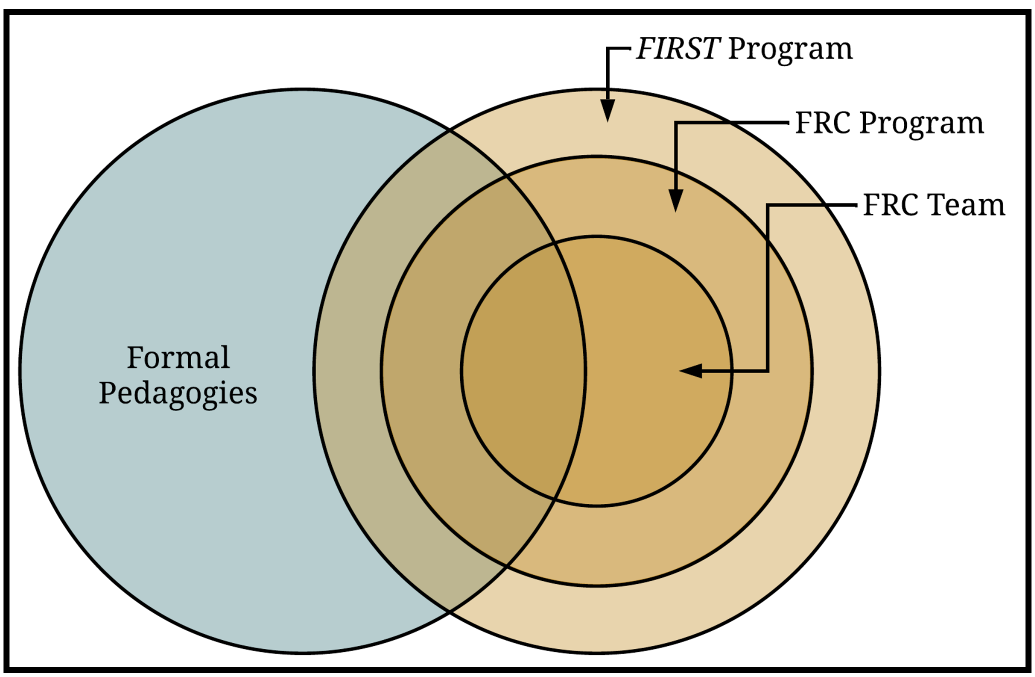
    - Practice: Competing with many robots at *FIRST* Robotics Competition Events.
- FRC Team (A single build space for FRC students)
    - Practice: Building a single robot with students grades 9-12.

While *FIRST*'s communities of practice share similar community members (mentors, volunteers and students), differing practices and domains result in practitioners' natural expression of legitimate peripheral participation to vary (Lave & Wenger, 1991). For example, on an FRC team, participants referred to commonly agreed-upon challenges such as the training of new mentors and the choice to instruct or facilitate technical tasks associated with building a robot. In contrast, at an FRC event, participants collectively discussed competitive strategy, the production of awards-based presentations, and social dynamics associated with subject-specific terms such as the "drive team."

Collectively, mentors demonstrated differences in agreed-upon challenges associated with varying communities of practice (Wenger-Trayner et al., 2023). As a mentor, participants demonstrated their contribution to *FIRST*'s community of practice by using *FIRST*'s domain-specific language (Verma, 2015) rather than the educational or research community. Participants demonstrated limited usage of formal language associated with pedagogical approaches. For example, when reviewing the study's letter of information (Appendix B) and artifact requests (Appendix E), participants asked clarifying questions such as "What is project-based learning?", "Have I created an artifact if I am a mentor?" and "What is constructionism?" which I addressed using language common to the domain of *FIRST*'s CoPs (Appendix F). Despite initially being unfamiliar with defining their mentorship approach, participants demonstrated an interest in understanding more information about how to describe their practice using technical language (e.g. one participant sought out resources about instructional vs constructionist learning environments). Similarly, participants articulated challenges for new mentors in engaging with their FRC team's CoP, which they attributed to a lack of familiarity with technical terminology as an FRC mentor (see section 5.2.2).

Figure 5.2

Education & FIRST CoP Domains



Throughout the study, mentors agreed with the constructionist approach to developing a socially safe, low-stakes educational environment (Dwivedi et al., 2019; Franck & Donaldson, 2020). For example, shared sentiments such as Megan's thought that: “robotics should be a social space” and Brinn’s emphasis that her FRC team “should be a space where the kids can go to be kids, hang out, [and] interact with people” touch on numerous experiential and CoP and constructionist studies (Verma, 2015). Throughout the study, participants indicated the importance of maintaining a socially safe, close relationship between mentees and mentors, where mentees could learn about STEM outside the traditional graded school setting.

Further, participants link the evidence of mutual trust, inclusivity, and diversity (Lee, 2018; Miranda-Diaz, 2021; Wickliffe et al., 2020) to personal success and motivation as a mentor using terms and phrases like “Core Values” and “Inspiration and Recognition of Science and Technology.” At one point in her interview, Amelia reflected that when a student shared that they looked up to her as a mentor, she felt, "I am being inspiring! I’m doing the ‘I’ in *FIRST*; I can retire!” Though she shared her sentiment jokingly, Amelia’s statement points to *FIRST*’s acronym (For Inspiration and Recognition of Science and Technology), core values (Discovery, Innovation, Impact, Inclusion, Teamwork, and fun), and methodology as self-evaluative metrics for success as a mentor (FIRST, 2022b):

> [U]se strategies known to increase student interest in STEM: hands-on learning, working as a team on real-life problems, exposure to careers and adult mentors, emphasis on *FIRST* Core Values, and a culminating celebration where students can showcase what they created and learned.

FIRST’s methodology utilizes similar terminology with project-based learning theories of education such as “hands-on learning,” “working on real-life problems,” and “showcasing the culmination of learning,” which participants described throughout their mentorship interviews and submitted artifacts. Despite the overlap of both practices' application of youth education, formal educators and FRC mentors use varied technical terminology and non-verbal cues to describe examples of "effective" and "ineffective" mentorship.

During interviews, participants who identified as *FIRST* alumni (Brinn, Jace Hammervik, Joel, Kamal, and Megan) shared similar descriptions of the evolution in their mentorship as new mentors, contrasting with their mentorship approach in the 2021-2022 season. Once burnout and frustration were identified, participants shifted their mentorship approach from instructional to facilitating. However, participants' lack of familiarity with key terms such as "instructional," "facilitating," "project-based," or "constructionism" associated with an educator's CoP prevented them from engaging more profoundly in a technical discussion surrounding the steps to their mentorship approach.

5.2.3.1 Ineffective Mentorship

Similar to instrustionism's passive learning transfer approach (Alberta et al. Resources Branch, 2004; Papert & Harel, 1991), near-peer mentors described their initial approach to mentorship as a role where the mentor was a formal "knowledge expert" that provided step-by-step instructions to mentees in order to reproduce an "ideal product" in the form of a competitive robot or essay submission. As mentors who guided a project-based learning problem from an instructional approach, participants used descriptions like being "directive," "hands-on," "prompting," "assigning jobs," and “guiding mentees to the answer I thought was correct” to their mentorship approach in their first season of mentorship. Similar to Papert & Harel’s (1991) description of common classroom tools like lectures and textbooks, mentors commonly shared examples of past work that they expected mentees to structure essays and robot mechanisms. Mentors provided examples were often award-winning essays or competitively successful robots, which participants used as a determining factor for sharing with mentees as an “ideal goal.” In opposition to constructionist’s low-stakes, playful and relaxed environments (Kynigos, 2015; Psenka et al., 2015), near-peer participants who initially adopted an instructional approach described their team as being “more competitively motivated” in comparison to their mentorship approach in the 2021-2022 season, where they adopted a more facilitating approach which de-emphasized evaluation as a metric for success.

Of the five participants in the study who identified as *FIRST* alumni, participants who had experience as a mentor for 3 *FIRST* seasons or more (Brinn, Kamal & Megan) were able to identify the impact of their instructional approach on mentee’s engagement and subject-specific skill transfer (Witherspoon et al., 2018), as well as describe changes to their mentorship style in future seasons. For example, after mentoring with an instructional approach for several *FIRST* seasons, participants identified that they became frustrated and burned out by the lack of participation and initiative students took on projects they led as mentors.

Participants described the result of their instructional approach as "students stopped learning when I gave them the answer," "mentees weren't doing the work on their own," "mentees didn't take the initiative," and "students on the team learned less than when I was a student because of the way I was controlling their process." Though mentors were not completing a project on behalf of the students, students also weren't wholeheartedly engaged in the project-based learning problems embedded in the FRC program's design. Similarly to mentorship engagement literature, participants faced a decision whether to continue participating in their capacity as a mentor or retire from their role as a volunteer in the FRC program due to a lack of satisfaction in their mentee relationship and ineffective mentorship training support (Cicchinelli & Pammer-Schindler, 2022).

5.2.3.2 Effective Mentorship

Though Brinn, Kamal, and Megan described noted shifts in their chosen mentorship approach from their first season as mentors and the 2021-2022 FRC season, more recent near-peer mentors such as Joel and Jace Hammervik described a desire to learn more about the act of mentorship as it applied to their FRC team. For example, Jace Hammervik shared that while they had strongly developed an inclusive and socially safe team culture, their lack of familiarity with technical areas of FRC mentorship, such as mechanical engineering, was an area where they were actively seeking 1:1 mentorship from more experienced mentors on their team (as described in 5.2.2). In contrast, though Joel did not acknowledge the educational community as a CoP, he described an awareness and sense of "otherness" when comparing his mentorship approach to that of a formal educator, sharing that "I wasn't given a lot of guidance on how to mentor because the [only other mentors were] teachers [and they were trained as educators]. They already had the skills to mentor" (Table 4.1). Joel and Jace Hammervik's experiences reflect an innate desire to become a part of their FRC team's CoP and learn about mentorship resources from existing community members to become effective mentors.

In the 2021-2022 season, Brinn, Kamal, and Megan described their recent mentorship practices as near-peer mentors more closely aligned with both constructionist and project-based learning facilitation practices. Instead of providing a list of instructions with a timeline of when to complete tasks, mentors de-emphasized the importance of competitive success at competitions, reducing mentees' perceived evaluation (Psenka et al., 2017) of their produced artifacts (a robot or essay). By allowing mentees to explore the research process without step-by-step guidance, mentors began demonstrating more flexibility in the learning paths available to mentees, resulting in more active participation from their mentor-mentee relationships (Kynigos, 2015). For example, participants like Megan and Kamal described her team as "student-led," where students seek mentor support when looking for more effective problem-solving techniques but maintain ownership over their robot regardless of its competitive success.

After gaining personal experience from her instructional and constructionist mentorship style practice, Brinn's submitted artifacts (Figure 4.1, Figure 4.2, Figure 4.3) demonstrate her team's commitment to mentorship training and volunteer retention

(Franck & Donaldson, 2020). The team's teaching philosophy and creative control (Figure 4.1) as students maintain ownership of their schedule, division of tasks, and materials, further emphasizing the importance of a mentor's just-in-time support (Sahin, 2013; Yoel et al., 2020).

5.3 Developing the FRC Community

FIRST as an organization has responded to calls for educating and including diverse youth in response to STEM's historic leaky pipeline (Hennessy Elliott, 2020). *FIRST* demonstrates a general commitment towards EDI as demonstrated by organizational core values such as "inclusion" and program-level awards placing values of community service above all competitive success (e.g. the Impact Award, formerly the Chairman's Award). Across the literature, OST youth programs following the FRC program refer to their organization as a "team" rather than a group or course, demonstrating immersive feelings of inclusion and belonging aligned with educational psychology (Dwivedi et al., 2021). Throughout interviews, all participants expressed the sentiment that in comparison to other OST STEM programs and competitive robotics programs (e.g. VEX, Science Olympiad), *FIRST* authentically demonstrated a commitment to developing inclusive and supportive communities. As an organization, *FIRST* consults with greater community members to support inclusion based on identity factors such as gender and sexuality, cultural and racial background, and disabilities. For example, in 2022, the FRC program updated its most prestigious award to remove historically gendered names, updated banned music played at events containing negative racial undertones and continually developed the implementation of quiet rooms, prayer rooms, and individual accommodations at competitions (Merrick, 2022).

While FRC program resources demonstrate *FIRST*'s organizational commitment to the inclusion of diverse youth through projects such as media campaigns and grants for the support of underrepresented youth (Center for Youth and Communities, 2011), within the recent academic literature, *FIRST* as an organization has focused on equity, diversity, and inclusion initiatives focused on skill attainment and post-secondary enrollment rates for program participants (e.g. Burack et al., 2019; Meschede et al., 2022), rather than research involving program mentors (e.g. Center for Youth and Communities, 2011). Demographically, *FIRST*'s most recently published mentorship demographics for FRC mentors (Center for Youth and Communities, 2011) document that FRC mentors are 82-85% Caucasian, in unfortunate alignment with the overrepresentation of census data for volunteer coaches and mentors in Canada (Hahmann, 2021) and America (Americorps, 2023). The more complex the technical OST program, the higher the gender divide between participants in STEM youth programs (Witherspoon et al., 2018). Notably, while volunteer demographic data does not equate to the success or failure of authentic inclusion of an OST youth program (Kekelis et al., 2017; Powers et al., 2015), mentors lacking the lived experience of historically racialized, underprivileged, or excluded peers require higher degrees of acceptance of cultural differences and empathetic awareness (Kim et al., 2021) in order to meaningfully develop respectful relationships with fellow mentors and mentees in a youth program. Further, the mentor's comfort with engaging in conversations that validate the mentor or mentee's lived experiences has been found to increase the mentee's ability to overcome barriers to STEM career success (Powers et al., 2015). While demographic backgrounds, including age and socio-cultural factors, have influenced mentors' empathy and engagement with diverse youth in mentorship programs (Miranda-Diaz et al., 2021; Peifer et al., 2016; Powers et al., 2015), practical training programs provided by a youth program's organization (such as *FIRST*) can provide meaningful support that model expectations for exemplary (and appropriate) mentorship expectations for new volunteers. This study's secondary research objective identified FRC mentors' identification of approaches to developing inclusive, informal learning communities.

As mentors with multi-faceted identities, no participant described a single identity (e.g. gender and sexuality, presence of disabilities, age, socio-cultural factors) as the sole influence on their approach to mentorship. As such, the development of themes related to identity and belonging for both students and mentors is presented in a single, unified section celebrating participants' collective intersectional approach to mentorship. Two major themes emerged in the findings: (a) the development of feelings of identity and belonging on an FRC team (5.3.1) and (b) descriptions of authentic engagement in EDI practices within *FIRST* (5.3.2).

5.3.1 Identity & Belonging

Throughout the study, mentors demonstrated varying levels of comfort and ability to communicate how intersectional aspects of their identity influenced their feeling of inclusion within FRC. As a volunteer-facilitated program, all mentors unanimously described program-level barriers as mentors, including burnout and volunteer recruitment challenges (Aresi et al., 2020).

Throughout the interviews, several participants shared that their level of income, role as a caregiver, and required ability to commute to mentor had actively prevented their participation as a volunteer within *FIRST* in some way since they first joined, of which no participant described feelings or resources that supported their participation as a mentor. For example, participants like Maddie shared that often in her time as a Lead Mentor of her robotics team, the cost of food in her area was so high that she chose not to eat in order to continue holding robotics meetings for students as one of the team's only dedicated mentors. As with Teye and Peaslee's research (2020), participants in the study demonstrated a high motivation to make the world a better place (sometimes at the sacrifice of their well-being), followed by a desire to understand the world's diverse people. All participants identified as *FIRST* alumni specifically returned to mentor the program that impacted them as students, building on Powers et al. (2020) research. Of the eight participants in the study, six mentors were aged 20-30, while several held caregiver roles, multiple jobs, and utilized public transit as their primary means of transportation. Despite sharing more themes related to personal barriers associated with mentoring, participants between 20 and 30 described their motivation to mentor as "seeing the impact on students," similar to Hahmann's (2021) identification of Canadian's motivation to contribute to the well-being of their community.

Previous literature has illustrated the historically racialized and gendered environments that can be perpetuated within *FIRST* teams whose mentorship does not consider EDI (Hennessy Elliott, 2020). As the only participant identifying as a middle-aged caucasian male with no experience with disabilities, Cade was one of the few participants who did not describe any times when he felt he did not belong as a mentor. Though he mentored outside of his time as a paid educator, Cade felt supported by his workplace and the First Nations community in which he resided, clearly communicating his role as "invisible" (4.3.3.1). Contrasting Hennessy Elliot's (2020) mentorship approach valuing competitive success, Cade celebrated his students' identity as a First Nations team, emphasizing the development of socially safe environments and its influence on the students who chose to participate in his team's "drive team" at robotics competitions. Throughout his interview and submitted artifact, Cade openly discussed the influence of gendered and racial barriers on students' competitive achievement within FRC through quotes such as

> There's definitely forces that our kids push against every day that other teams wouldn't [know] are barriers. You really see the contrast between the worlds of privilege and the worlds of racism and historical exclusion. If you just walk around the 600 teams at worlds and look at how many Black and First Nations teams, there are not many.

Similarly to the literature documenting other First Nations community's OST STEM programs, Cade described barriers related to systemic racism, inconsistent governmental support, and significant challenges in training and recruiting new volunteers to support the program (Jin, 2021; Koomen et al., 2021). Though Cade did not discuss any personal barriers associated with mentorship other than recruiting and retaining new mentors, he demonstrated a profound respect for the mentees he served in his team's CoP. As a mentor, Cade leaned on his historical background as an educator to respectfully engage with students navigating historical racism, financial barriers, and the death of several team members within his community.

Participants' ability to access STEM environments significantly impacts their ability to serve in a facilitator role meaningfully for students. As with Cade's identity as "being invisible," participants like Brinn were motivated to support the development of their mentees, sharing her approach to developing empathy with her students:

> If [students] asked me personal questions, I wouldn't say no to having a conversation. [...] I let myself be known as a person who will be straight with the kids and make sure that I'm very open. They usually know that they can come to me with any issues that they have and that it's a safe space where they can talk about stuff. I try to bring that into my mentoring by saying, "this is what we're all going through; you don't need to be ashamed of it."

Similarly to Brinn and Cade, Jace Hammervik demonstrated high degrees of comfort with their identity with students as part of the core development of a mentor-mentee relationship. As a mentor, Jace Hammervik faced various visible and invisible barriers to accessing their *FIRST* team, including using physical mobility devices. As a mentor, Jace Hammervik is open with their students, sharing in their interview that

> I'm open about my mental and physical health because I have to be. It plays a role in who I am. I can't really hide my ticks. I have a tick disorder. That's not something I can hide. I can't hide the fact I walk with a cane. So I'm very open about that and try to normalize stuff in this space. So a lot of the kids who feel like they stick out in any way have gravitated towards me as a mentor who offers them support through getting through the program. As queer people, or as mentally ill people, that kind of thing.

Like Jace Hammervik, Megan demonstrated vulnerability with her mentees throughout her gender transition in the 2021-2022 FRC season. Despite oppressive comments she received outside of the *FIRST* community about her choice not to hide her gender transition as a mentor, Megan openly continued contributing to her team's community of practice, building a socially safe environment focused on diversity and inclusion (Hennessy Elliott, 2020; Phelan et al., 2017; Renken et al., 2021). Though Megan was proud of her contribution to *FIRST*'s community of practice and felt safe in openly discussing the impact of her identity on her mentorship, she shared feelings of unease about her identity external to *FIRST.* For example, Megan shared that. "sometimes it can be easier if you're not open with [your] identity. I do find it important when I'm doing the mentorship to try to represent my identity and be useful."

As near-peer mentors, *FIRST* alumni such as Brinn, Jace Hammervik, and Megan demonstrated a heightened ability to build empathetic relationships with mentees by sharing both visible and invisible identity factors (Kim et al., 2016), while Cade demonstrated elevated rates of ethnocultural empathy as a means of building an inclusive *FIRST* team (Miranda-Diaz et al., 2021; Peifer et al., 2016; Powers et al., 2015). Similarly to youth mentorship literature, the presence of lived experiences and willingness to share openly with fellow mentees allowed mentors to contribute to socially safe team culture and deeply discuss mentees' identification of complex societal barriers within the context of their team's CoP. Further, despite experiences where participants felt it was safer to hide their identity in communities external to *FIRST,* mentors' FRC teams served as a safe space to openly develop their identity without fear of repercussion.

Despite previous literature (e.g. Hennessy Elliot, 2020) documenting the dangerous impact of mentors' lack of comfort in confronting STEM's historically racialized and gendered environments, participants in the study demonstrated a strong motivation to build equitable team spaces openly and were unafraid to point out *FIRST*'s continued opportunity for growth in increasing equitable representation at FRC events such as World Championships.

5.3.2 Engaging with EDI

Although all participants could discuss the importance of Equity, Diversity and Inclusion, they demonstrated varying levels of conceptual understanding for developing inclusive FRC teams in their mentorship practice authentically. Throughout the interviews, participants identified and analyzed examples of their lived experiences and engagements with EDI, using broad examples describing their resulting mentorship practices. In the classroom and OST PjBL environments, mentors are encouraged to implement facilitation techniques by considering the power dynamic between mentees' ability to access and participate in a program (Kokotsaki et al., 2016).

As new FRC mentors, *FIRST*'s online slide-based EDI and mentor training describes the importance of *FIRST*'s core value of inclusion (FIRST, 2022b) as a guiding principle to encouraging diverse student and mentor populations to participate on a team. While mentors like Jace Hammervick noted the importance of learning about EDI and terminology surrounding inclusion (5.2.2), they also shared that a mentor's lack of personal experience as an underrepresented population will not provide a mentor with the lived experience to create and host EDI-focused resources. Mentors must be prepared to engage with complex social issues outside of technical mentorship, analyze contextual factors and respond appropriately in support of youth. Participants who served as Lead Mentors of their FRC team described additional feelings of responsibility and societal pressure to maintain the safety and emotional well-being of youth or fellow mentors on their robotics teams.

5.3.2.1 Inauthentic EDI Engagement

Without further PjBL style training for mentors or a 1:1 mentorship between rookie mentors and those experienced with facilitating conversations about adversity (e.g. Powers et al., 2015), FRC mentors have a high risk of attempting to with EDI unsupportively. Mentors' lack of developed empathy and comfort in facilitating socially safe environments risks practices common to new FRC team EDI initiatives, such as the recruitment of underrepresented youth and mentors in efforts to "diversifying" their team through tokenistic practices. While well-meaning, participants in the study demonstrated a range of aptitude and experience with developing inclusive *FIRST* teams and an overall sense of uncertainty due to a lack of feedback or training on "how not to do it wrong." For example, when describing a time when students of colour joined her FRC team of exclusively caucasian mentors, Claire repeated the slogan "If you can see them, you can be them" to acknowledge her lack of lived experience in supporting racial diversity within her mentorship practice.

Though she understood the importance of identifying systemic barriers unique to historically racialized students, and she acknowledged her lack of experience with doing so, Claire described, with a feeling of urgency, her search to recruit mentors who were "qualified" to support diverse student needs, and felt as though that this practice was the only solution available to support the new students on her team. Even though participants such as Claire and Joel had completed *FIRST*'s EDI training and were able to repeat terminology or slogans associated with it, mentors who did not have any other hands-on training or workshop experience on EDI topics believed that while EDI was critical to their FRC team, their duty as a mentor was exclusively to find and recruit new mentors who possessed the lived experience in response to diverse students joining the team.

Instructional-style training modules do not engage learners in active learning by producing an artifact of inquiry over an extended period (Kokotsaki et al., 2016; Lee, 2018; Lee & Galdino, 2021), which could be a contributing factor to the demonstrated novice-level understanding of EDI displayed by participants as they described their first season in FRC. During her interview, Amelia demonstrated an example as a new mentor when she led her team through a potentially inauthentic EDI initiative. As both the students and mentors on her team described themselves as feeling "socially weird" and "robot nerds," mentors led their team through a core values exercise that she described as

> We ended up settling on that our team really values individuality. When we settled on it, it was more "individuality, we're all robot nerds and we also have women on our team who are robot nerds look at us." There was one token black kid on our team and a handful of Indian kids, so we thought, "Yeah, diversity."

During her interview, Amelia demonstrated that she did not believe that the team's core values exercise authentically supported the diverse populations on her team by using sarcastic hand waving when sharing "yeah, diversity" and her frowning facial expressions. Her quote also acknowledges her understanding of tokenism, a concept introduced during *FIRST*'s EDI training module for mentors (FIRST, 2021a).

Though participants demonstrated a genuine goal to meaningfully support both students and mentors in FRC, as with findings of mentorship across the literature (e.g. Kekelis et al., 2017; Kim et al., 2016; Powers et al., 2015), mentors who lack personal lived experience with adversity and lack of formal training for authentic or ethical inclusive practices may engage with non-supportive policies that prevent the growth of underrepresented mentors and students. During their interviews, participants like Amelia, Joel, and Claire shared a fear of "getting it wrong" when supporting diverse mentees and fellow mentors on the team who may require additional support. In contrast to Joel and Claire, Amelia described an essential aspect of her mentorship as asking "more experienced mentors" about how they would handle social situations and actively learning about "allyship" when she lacked personal lived experience. As mentors, both Claire and Joel shared feelings of urgency during their interviews surrounding the feeling of "having to recruit qualified mentors" in order to support diverse mentee needs "before they quit the team." In contrast, Amelia articulated her understanding of inauthentic engagement with EDI as a new mentor, demonstrating her lack of agreement with her past practices through sarcastic gestures and frowning facial expressions as she remembered acts of tokenism as a rookie mentor. Though all three participants described engagement with some type of instructional-style EDI training as a source of definition-based knowledge related to their mentorship practice, Joel and Claire could not describe how they had personally researched or reflected on EDI-based initiatives outside of the instructional training. In contrast, Amelia reflected on years of PjBL-style independent research and constructed artifacts that supported the development of her mentorship practice.

5.3.2.3 Authentic EDI Engagement

Throughout the study, participants shared stories surrounding the development of their mentorship practice as volunteers, both with personal lived experiences and as a mentor who supported the inclusion of diverse identities. Of all the study participants, only Jace Hammervik demonstrated high degrees of comfort with utilizing terms such as "intersectionality" and the impact of tokenistic or inauthentic practices of EDI initiatives on a *FIRST* team. Despite recently joining their team as a mentor, Jace Hammervik spent substantial time producing artifacts related to their EDI practice, including creating hands-on workshops, curating technical resources, and hosting reflective conversations with fellow mentors on their team. Though Jace Hammervik had lived experience with several underrepresented identities in STEM, they also engaged with the support of resources related to Indigenous students and cultural diversity.

As a mentor, Jace Hammervik recommended meaningfully curating a safe space regardless of perceived individual identity. In their interview, Jace Hammervik used excited and emotional gestures to emphasize the importance of not singling students and mentors out for perceived differences. For example, a mentor taking the initiative to create resources for a single team member without being asked can jeopardize feelings of belonging within the team's existing CoP. Though Jace Hammervik also completed *FIRST*'s EDI training (FIRST, 2021a), in contrast to inauthentic engagement with EDI topics, Jace Hammervik and their fellow mentors took the time to complete training as a team, socially engaging in the process of research and reflection (Papert & Harel, 1991; Psenska et al., 2017), asking, "How do we make this space safe for more students to join?"

As a team, Jace Hammervik and their fellow mentors created a self-guided exploration of their CoP's engagement and understanding of EDI separate from their active mentorship practice. Throughout extended inquiry (Kokotsaki et al., 2016; Lee, 2018; Lee & Galdino, 2021), Jace Hammervik researched and created an artifact of learning (in the form of an EDI workshop), which they socially presented to fellow mentors. As a result, fellow mentors on the team have shared with Jace Hammervik that they have seen a notable impact on the culture and practice within their FRC team, demonstrating their team's authentic engagement with socially complex topics relevant to EDI (Dwivedi et al., 2021; Kekelis et al., 2017).

Participants in the study who had engaged in extended inquiry surrounding EDI felt confident discussing their inclusive mentorship practice. They wanted to create resource-based artifacts supporting CoPs beyond their FRC team. For example, having facilitated EDI workshops within their team's CoP, Jace Hammervik expressed a desire to engage with *FIRST* program organizers within their local CoP. During their interview, Jace Hammervik shared that as a person with disabilities, they "really want to have an impact, and one of the things I want to do is to communicate directly with *FIRST* Canada and brainstorm how we can make the program more accessible for people."

Though Jace Hammervik described their team's explicit engagement with extended inquiry on the topic of EDI, other participants in the study also reflected on their research and presentation of artifacts as they related to the authentic development of inclusive *FIRST* teams. For example, Amelia described the intense pressure she felt as her team's Lead Mentor in supporting students who came out to their team as transgender over the summer. While Amelia and her team had confidently been supporting gender-affirming initiatives (such as supporting student-led initiatives for team members to wear pronoun pins throughout the season) with normalcy all season, she was anxious about how to support students equitably without making parents on the robotics team angry about sleeping arrangements on overnight trips. Lacking the personal lived experience of a gender transition and not knowing any mentors with experience supporting students on overnight trips, Amelia felt overwhelmed and unprepared to make any member of her team feel isolated while also socially responsible that parents would be angry with her for making "an inappropriate rooming list."

Amelia maintained responsibility for the organization of the trip but decided to put aside her fear of "not knowing how best to support the students" by hosting individual conversations with all team members to ask what would make them the most comfortable. Amelia demonstrated her growth as a mentor practicing EDI by maintaining ownership of the emotional and organizational labour associated with organizing the trip while authentically seeking advice from students with lived experience (Kekelis et al., 2017; Powers et al., 2015) about how best to support them. Amelia recognized her commitment to the growth of inclusive practices on her team and demonstrated the importance of maintaining a socially safe environment (Aresi et al., 2020; Davis et al., 2021; Koomen et al., 2020) that supported all students in her robotics team to equitably participate in important field visits, where they could present their artifacts (their robot) socially.

Had Amelia allowed the societal pressure from the greater community to influence her reaction to the robotics team, she may have required that the students sleep by themselves in a hotel room, leaving them to feel isolated and choose to stop participating (e.g. Hennessy Elliott, 2020). Instead, Amelia recognized the importance of maintaining an empathetic relationship with her mentees and continuing to support their team's community of practice by sharing inclusive resources (Davis et al., 2021; Hennessy Elliott, 2020; Koomen et al., 2021; Verma, 2015). Despite Amelia's limited experience with formal research practices surrounding EDI, like Jace Hammervik, she demonstrated an ability to contribute to discussions and display a nuanced understanding of social issues related to their mentorship practice.

5.4 Summary of Discussion

The study's discussion highlighted significant insights gathered from the findings (4) and informed by relevant literature (2). Participants collectively engaged with two major themes surrounding learning to mentor (5.2) and engaging with EDI (5.3), which have been summarized below.

1. Using project-based learning phases and constructing an artifact of mentorship provided positive results for participants' communication of mentorship techniques.
2. As informal educators, participants demonstrated limited usage of language associated with pedagogical approaches. However, they were interested in learning more about technical terminology to describe their mentorship practice, such as CoPs, PjBL, and constructionist versus instructional learning approaches.
3. Participants constructed CoPs at the FRC team level by emphasizing that "robotics should be a social space" while engaging with legitimate peripheral participation as mentors by learning about effective and ineffective mentorship.
4. Participants defined ineffective mentorship approaches aligned with instructional style, while they defined effective mentorship synonymously with constructionist environments.
5. Similarly to existing literature, participants described personal burnout, training requirements, and program-related barriers such as finances and available time to

impact their mentoring ability, disproportionately affecting mentors historically underrepresented in STEM.

6. Participants who did not face barriers to STEM demonstrated allyship and high degrees of empathy through their identity of "being invisible" as a mentor.
7. Mentors who only had experience in instructional-based training were likelier to exhibit inauthentic engagement with community development, including tokenistic recruitment of mentors and students and misunderstanding phrases such as "if you can see them, you can be them."
8. The most authentic development of EDI was developed through extended inquiry processes as a group of mentors, following PjBL's phases of inquiry.

6 Conclusion

The following sections in this chapter conclude the body of the thesis. First, the study limitations are outlined in section 6.1, including details of participants (6.1.1) and the study's research design (6.1.2). Next, recommendations for future research are summarized in section 6.2, followed by implications for the broader field of educational research in section 6.3. Finally, the thesis is concluded in section 6.4.

6.1 Study Limitations

As an exploratory study, this thesis aimed to contribute to understanding how informal educators engage with high school-aged students through youth STEM programs. While optimistic, the results of this short-term project cannot make claims about mentors' lasting engagement with youth STEM programs and active engagement with authentically inclusive environments. As a result of the short-term project, the study presented several limitations that restricted the scope and should be considered should this study be replicated. The limitations affected the study participants and research design have been presented in the following sections.

6.1.1 Participants

From the planning stages of the research study, the participant pool posed a limitation. Study recruitment primarily occurred (a) online and (b) through channels associated with FRC and FTC events in Ontario. In-person recruitment was facilitated verbally through the volunteer registration and administration table at events during the

2021-2022 season. This recruitment strategy may have favoured mentors and teams who operated close to the in-person event or were otherwise comfortable with mentorship in high-stakes environments. Participants' pre-study questionnaires and early study responses hint at this being the case, with all but one participant's self-rated mentorship rated three or more on a 5-point scale. Further, the limited sample size does not represent the full scope of mentors' roles on an FRC team, especially considering that each participant had a unique experience mentoring diverse teams across the Ontario FRC District during the 2021-2022 season.

As only active FRC mentors of teams in the Ontario District were contacted, participants who were primarily passionate about supporting youth mentorship programs and developing inclusive youth programs considered EDI. Though more than half of the participants had engaged in youth mentorship of other youth programs (Pony Club, Girl Guides, VEX, Science Olympiad), due to the context of the study, the interview was not explicitly designed to probe participant experiences between programs. As such, potential bias toward participants' positive perception of the effectiveness of the FRC program with engaging youth and mentors and the importance of developing inclusive youth programs is a limitation of the study.

Though all participants were familiar with EDI as a result of taking part in online mentorship training from *FIRST* (FIRST, 2021a), participants exhibited a range of comfort in discussing the development and personal experiences with STEM identity and factors that contributed to or inhibited their individual, or their students' STEM identity.

As the study was designed to examine participants' experiences of EDI, intersectionality, and STEM identity, with copies of informal interview questions (Appendix D) shared before all interviews, participants demonstrated varying engagement with deeply personal and potentially emotionally charged topics. When participants expressed discomfort in probing particular elements of identity or sharing in greater detail (mainly related to socio-cultural factors for all but one participant), I chose not to pressure the conversations that were not naturally arising. This choice was primarily made as my duty as a researcher to maintain participant comfort and safety, especially considering the potential negative emotions that may arise in an unfamiliar setting such as a research study.

6.1.2 Research Design

Qualitative research designs have several limitations preventing generalizing results to a larger population. As qualitative inquiry is conducted in naturalistic settings rather than controlled environments (Braun & Clarke, 2006; Creswell, 2013), environmental conditions are limited to this data set. As a result, the context of the 2021-2022 season and the teams each mentor supported influence how mentors may apply educational practices. How one participant behaves in context does not translate precisely to another (Creswell, 2013; Merriam, 1988; Patton, 2002). Next, the researcher must interpret the data, and interpretations of the data are inevitably informed by my subjectivities and potential biases (Creswell, 2013; Merriam, 1988; Saldana, 2016). To reduce the impact of potential bias, I've prioritized reflexivity throughout all stages of conducting and reporting this thesis (see 1.2 Positionality Statement).

As a result of these limitations, the findings in this study should be considered for their ability to transfer to other settings rather than intended to be generalized. As such, the study context, procedures, and data have been described in detail to aid in comparing other environments and groups of educators (Creswell, 2013; Stake, 1995). Triangulation and continued communication with research participants across cases lend to the validity and reliability of findings within this context (Stake, 2006; Miles & Huberman, 1994). Further, the use of multiple cases in combination with cross-case analysis allowed for an insight into participants' experiences and potential contributing factors (Creswell, 2013; Miles & Huberman, 1994; Stake, 1995). Future research must be conducted to allow for the generalization of volunteer educational practices of mentorship in inclusive STEM environments.

As the study was limited to participant perceptions of their volunteer engagement after the 2021-2022 FRC season in Ontario, the short timeframe prevented any insight into the long-term effects of mentorship, such as the continued engagement of inclusive spaces or the development of mentorship practices in future seasons. Given a more prolonged study duration, participants could meaningfully engage with mentorship in greater depth, establish meaningful connections with EDI within their team, and spend more time conceptualizing the act of mentorship as it relates to educational practices.

The study also suffered some limitations related to data collection instruments. As the study took place during COVID-19 gathering restrictions, all data was collected remotely, which limited the depth of the ability to collect observational data throughout participant interviews. Despite the limitation of the virtual interview format, due to existing rapport and familiarity with myself as an active participant, mentor, and volunteer of *FIRST* programs in North America, participants vulnerably engaged in multiple forms of virtual data collection throughout the study (see: 3.5 Data Collection Tools). Further, throughout the study's analysis and writing stage, participants continued to engage in the review and validity of findings within the study. In future studies, the prioritization of building 1:1 rapport between researcher and participants and the flexibility for multiple sources of data collection and artifact submission will continue to enhance the rich data collection in a virtual environment.

Due to the broad definition of the study's request for "artifacts of mentorship," many mentors first responded to my requests by sharing that they were "unsure" that they had any examples of how they mentor. Generally, partially due to the lack of formal educational training and the context of *FIRST*'s PBL model, Participants almost exclusively viewed students as the sole "producers of artifacts" and mentors as "facilitators to the production of artifacts." After sharing examples of my artifacts (Appendix F) throughout participant interviews, half of the participants (four) submitted personal examples of artifacts for consideration in the study, with one participant enthusiastically submitting six separate examples of their mentorship. In future studies, it is recommended that any language surrounding the word "artifact" be reworded to be more approachable to informal educators to reframe their conceptual practices of mentorship.

6.2 Future Research

This study was designed and conducted on a foundation of constructionist theories. While a breadth of research on informal STEM youth programs from practitioners has suggested promising implications for documenting informal educators' mentorship practice, these approaches still require validation. Future research should examine the affordance of the production of mentorship artifacts with mentors' engagement with technical subject-specific concepts like constructionism, project-based learning, and facilitation within the constraints of an informal education setting and their transferability to the classroom environment. Mentors are expected to support both the emotional development and technical-subject-specific skills transfer of youth STEM Programs to engage with FRC's mentorship. This study suggested using inquiry-based techniques to probe non-educators' self-study of mentorship practices. However, additional research is needed to explore the explicit development of mentorship artifacts under a period of extended inquiry. Mentorship training programs, particularly those designed for mentors outside of education, could be adapted from an instructional slides-based style to a facilitating constructionist methodology. Given mentors' ability to effectively describe mentorship practices when using an artifact of mentorship compared to informal interviews alone, future research should also investigate the impact of various project-based learning elements such as extended inquiry, exploration of technical terminology, and collaborative discussion to evaluate efficacy.

The findings and limitations of the research may inform future studies involving FRC mentors' lived experiences and the development of inclusive spaces for youth robotics. Despite historical connections to Seymour Papert through Distinguished Advisor Woodie Flowers (Ames, 2018; Benjamin, 2023; Martin, 1988; Sales, 1997), it is unclear whether *FIRST* refrains from using more technical terminology in more of their mentoring resources or offers further research in the field of education for interested mentors. Further, though *FIRST* celebrates the use of hands-on learning in the curriculum of annual student problem statements, the organization has displayed a varied approach to producing mentorship training, which is not historically hands-on or real-world problem-based (e.g. *FIRST*'s EDI training). While the findings in this study appear promising, it is likely that participants were predisposed to understanding EDI and were unfamiliar with the educational theories on account of recruitment procedures.

6.3 Educational Implications

Much like with *FIRST*'s encouragement and creation of project-based learning challenges, training modules targeted toward their volunteer base should similarly encourage the creation of an artifact of learning over extended inquiry (Almisis, 2012; Noss & Clayson, 2015; Psenka et al., 2017). The limitations presented in the present study (6.1) prevent the findings from generalization; however, the results suggest that adapted mentor training resources developed around project-based, extended inquiry, including the development and understanding of mentorship techniques and approaches to EDI for youth mentorship programs could facilitate mentor retention and program sustainability. Similarly to volunteer training programs, the present study benefited from a level of flexibility unavailable in an educator-based training program, including a lack of required curriculum and flexibility in season scheduling. This study corroborates previous research indicating that leveraging the presentation of constructed artifacts (Papert, 1980; Papert & Harel, 1980; Psenka et al., 2017) can effectively facilitate reflection of learning in community environments (Kokotsaki et al., 2016; Lee, 2018; Lee & Galdino, 2021). This study also offers meaningful implications identifying how mentors express self-directed learning about mentorship, particularly at the high school level. To date, STEM mentorship literature has primarily documented the motivations of mentors (Cicchinelli & Pammer-Schindler, 2022; Hahmann, 2021; Miranda-Diaz et al., 2021; Teye & Peaselee, 2020) and the implications of mentorship as it relates to youth program attainment in post-secondary education (Burack et al., 2019; Meschede et al., 2022).

The present study suggests that volunteer educators can develop a socially safe mentorship practice and engage with youth and fellow mentors about multi-dimensional identity factors influencing societally complex issues. This is noteworthy for the promotion of mentorship techniques for non-educators; beyond technical-skills transfer, mentors must also develop an understanding of facilitation techniques, authentic inclusion, and an understanding of how their mentorship practices support youth development outside of a youth program (Dwivedi et al., 2021; Kekelis et al., 2017).

The current emphasis on FRC mentor training and volunteer recruitment relies on instructional-based training programs or paid professional development workshop-style sessions (FIRST, 2021a; Simpson & Rodino, 2021). A mentor training approach matching that of the given youth program is required to meaningfully engage mentors in appropriate facilitation techniques and lessen the load of mentor training on existing mentors. The present study adds to the growing body of research and documents mentors' multifaceted identity and growth as non-educators and the relation between the educational community and a given STEM program's community of practice. Beyond a conceptual understanding of how non-educators learn about youth mentorship, this study highlighted the value of mentors' engagement with personal identity and self-reflection related to youth STEM programs. Previous literature has illustrated the roles of single and dual identity factors in developing student subject competencies (Aresi et al., 2020; Davis et al., 2021; Koomen et al., 2021). Constructionism (Alimisis et al., 2009; Anwar et al., 2019; Papert & Harel, 1991; Penska et al., 2017) and project-based learning (Blumenfeld et al., 1991; Helle et al., 2006; Lee, 2018; Sahin, 2013) enable mentors to explore the development of a socially safe and low-stakes environment that de-emphasizes competitive attainment through the production and sharing of meaningful artifacts (Dwivedi et al., 2021; Lee, 2018; Kokotsaki et al., 2016). Orienting non-educators' representation of mentorship through self-reflective artifacts empowers them to identify their mentorship practice while utilizing technical terminology related to diverse populations (Dolenec et al., 2015; Kekelis et al., 2017).

6.4 Conclusion

The findings of this study suggest that mentors' use of artifacts as an act of self-reflection can deepen personal presentations of informal educators' application of mentorship. In contrast to OST youth programs' theoretical alignment with constructionism (e.g. Alimisis et al., 2009; Anwar et al., 2019; Papert & Harel, 1991; Penska et al., 2017) and project-based learning (e.g. Blumenfeld et al., 1991; Helle et al., 2006; Lee, 2018; Sahin, 2013), available mentorship training programs for FRC mentors are primarily instructional or barred by cost-related or location-based access barriers. Despite informal educators' lack of engagement with the extended inquiry process in developing an artifact of mentorship throughout the study, the use of artifacts to guide their presentation and self-reflection made notable differences in participants' ability to communicate details, events, and examples of teaching methodologies as it related to their FRC mentorship.

Similarly to existing literature, mentors' lived experience and comfort in communicating personal identity concerning their mentorship have a notably higher description of mentor-mentee relationship satisfaction and the ability to communicate differences in approaches to developing authentically inclusive learning communities. However, the barriers participants commonly faced as FRC mentors were their own institutional and societal barriers associated with supporting FRC teams as unpaid educators. All mentors described demotivating themes such as burnout, frustration, and concern for program sustainability as stressors of their mentorship. Additionally, most mentors had personally faced societal or institutional barriers such as working multiple jobs, food insecurity, and the cost of travel to support required competition activities as a personal barrier to their mentorship practice that they did not commonly discuss with fellow mentors or students unless openly asked.

Non-educators who support youth STEM programs as volunteers should adopt facilitator-based mentorship practices instead of instructional-based programs. Further, in the absence of construction or project-based learning style mentorship training offerings, veteran mentors should seek to support new volunteers in 1:1 mentorship training programs for a minimum of 12 months, providing demonstration and opportunity for extended inquiry to develop personal mentorship practices. Participants' positioning of their mentorship as a practice allowed them to personally reflect on their growth as informal educators and share in several layers of communities of practice. Throughout interviews, participants demonstrated increased confidence in their mentorship practice and increased use of descriptive language to articulate their journey as a new mentor. Future studies should emphasize the creation of the extended inquiry process related to the development of mentorship development for informal educators and host a community-based presentation forum for mentors to present social artifacts of their inclusive community development.

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Appendices

Appendix A Initial Mentor Email

Thank you so much for agreeing to participate in an interview about your experiences as an FRC Mentor. I'm excited to hear the stories you have to share about your experiences.

I've also attached a letter of information with a consent form at the bottom. Feel free to ask any clarifying questions that you may have over email here and before our scheduled interview. Kindly read the letter, sign the consent form, and indicate your consent for your comfort level with recording methods.

Additionally, I'd love for you to complete the following pre-survey, of which every question is optional. As some of my research topics are to investigate how the identity of a mentor may impact or influence the approaches to their mentorship of youth, there are some questions about your gender identity, pronouns, cultural identity, and any disabilities you are comfortable with disclosing. Every question in this survey is optional, and you can choose to share what you are comfortable with.

At the bottom of the form is a list of sample questions that I have both for the pre-survey and semi-structured interviews. The nature of the Narrative Inquiry study is to understand your lived experiences through storytelling. Questions specific to your experiences may naturally come up outside the provided sample list.

Depending on your availability, I'd like to schedule a follow-up interview with you soon to ask additional questions based on your pre-survey and interview responses.

Appendix B Letter of Information & Consent Forms

Pages Seven to Nine of the Letter of Information & Consent forms contained the questions listed in Appendix C (Pre-Study Questionnaire) and Appendix D (Semi-Structured Interview Questions).

OntarioTech UNIVERSITY

Consent Form to Participate in a Research Study - Mentors

Title of Research Study: Non-educator motivations towards mentoring extracurricular grade 9-12 robotics.
Name of Principal Investigator (PI): Janette Hughes
PI's contact number(s)/email(s): Dr. Janette Hughes Janette.Hughes@ontariotechu.ca
Name of Student Lead:

- Katlin Walsh - katlin.walsh@ontariotechu.net

Departmental and institutional affiliation(s): OTU Faculty of Education

Introduction

You are invited to participate in a research study entitled "Non-educator motivations towards mentoring extracurricular grade 9-12 robotics". Please read the information about the study presented in this form. The form includes details on the study's procedures, risks and benefits that you should know before you decide if you would like to take part. You should take as much time as you need to make your decision. You should ask the Principal Investigator (PI) or study team to explain anything that you do not understand and make sure that all of your questions have been answered before signing this consent form. Before you make your decision, feel free to talk about this study with anyone you wish including your friends and family. Participation in this study is voluntary.

This study has been reviewed by the University of Ontario Institute of Technology (Ontario Tech University) Research Ethics Board [#13934] on [March 3rd, 2022].

We are teachers and researchers at Ontario Tech University. We are researching the motivations to mentor using a Narrative Inquiry approach. Narrative Inquiry is the process of collecting stories from individuals retelling their life experiences and identities to view how participants see themselves in a larger context. It uses chronology to allow participants to recall specific places, situations, or changes within their life history. More specifically, we are interested in the following questions:

A. What is the motivation for adult volunteers who are not educators to mentor grades 9-12 robotics clubs?

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B. What pedagogical approaches do mentors use when teaching students of diverse backgrounds, including students identifying marginalized or underrepresented STEM populations?

C. What are the lived experiences of volunteers who mentor robotics clubs?

We are asking for your consent to participate in our research project called "Non-educator motivations towards mentoring extracurricular grade 9-12 robotics". If you do provide consent, you will also be asked to provide assent. Assent means expressing approval or saying yes to participating.

Purpose and Procedure

Purpose

Participants will engage in semi-structured interviews with the researcher where they will share their personal experience regarding mentorship, FIRST Robotics Competition, and approaches to mentorship in STEM education.

Procedure

Information will be collected from participants at various times during the project. We will gather the information in the following ways:

- We will observe you during interviews and take notes about how you participate, what kinds of things you share.
- We will ask you to complete a questionnaire before the study begins (approximately 20 mins)
- We will observe you during a 1 hour semi-structured interview session and sessions and take notes (e.g., what kinds of things you discuss, comments you make and/or ideas you share)
- We would like to video-record and/or audio-record you for the same reasons as above
- We will conduct followup interviews at the end of the study (approximately 30 mins)

Video and audio recording of the research interviews will be conducted through a video conferencing platform. Examples of questions that we will ask you during the interviews are attached for your information.

In accordance with the evolving operational guidelines surrounding the COVID-19 global pandemic, the collection of information described above will take place in a secure online video-conferencing platform (e.g., Google Meet, Zoom) as needed. Only data collected from participants who have consented/assented themselves to participate in the research study will be used in the analysis and reporting of findings. Findings from this project may be published in journals and presented at conferences.

Participation Benefits

Potential benefits for participation in this study include: learning new approaches to mentorship and real world connections; having additional academic support in mentorship from the researchers.

Participation Risks or Discomfort

Potential risks include feeling pressured to share or embarrassment from sharing and feeling coerced into participating in the research because other participants appear to be. Risks will be dealt with in the following ways: researchers will explain to participants that they have the right to pass when it comes time to share their experiences. They will also explain that the participation in the research portion of the study is entirely voluntary and that they may choose not to participate at any point.

Usage & Storage of Data

The information you provide will not be stored with personal identifiers, nor will you be identified in any recorded or published comments. All information collected during this study, including personal information, will be kept confidential and will not be shared with anyone outside the study unless required by law. You will not be named in any reports, publications, or presentations that may come from this study. All identifiable data will be stored on a secure, encrypted drive at Ontario Tech University. Only identified researchers with Ontario Tech University will have access to the data. All data will be destroyed after five years. By consenting to participate, you do not waive any legal rights or recourse.

Confidentiality

The information that you provide will not be stored with personal identifiers, nor will you be identified in any recorded or published comments. All information collected during this study, including personal information will be kept confidential and will not be shared with anyone outside the study unless required by law. You will not be named in any reports, publications, or presentations that may come from this study.

Your privacy shall be respected. No information about your identity will be shared or published without your permission, unless required by law. Confidentiality will be provided to the fullest extent possible by law, professional practice, and ethical codes of conduct. Please note that confidentiality cannot be guaranteed while data is in transit over the Internet.

Voluntary Participation

You may withdraw from the study at any time without penalty. You can choose not to answer specific questions. If, during any of the above-described, you decide not to participate, you can end involvement in the activity by approaching the researcher and indicating that you wish to no longer participate (either in the activity or the research study, as a whole). If you withdraw from the research project at any time, any data or materials that you have contributed will be removed from the study and you do not need to offer any reason for making this request.

You may communicate refusal verbally or nonverbally.

The research component is not tied to any grading or student evaluation of any kind, and therefore you should not feel obligated or compelled to participate in the research for this reason. Participation in the research is entirely optional and you will not be penalized in any way if you do not participate.

Conflict of Interest

Researchers have an interest in completing this study. Their interests should not influence your decision to participate in this study.

Compensation, Reimbursement, Incentives

There is no compensation for participation in this study. Participants will also not incur any expenses as a result of their participation in this study. If a participants decide to withdraw from the study, they will not suffer any disadvantage or reprisal for withdrawing.

Debriefing and Dissemination of Results

After research has been completed and we have drafted our first report, we will share this with all participants. We plan to publish our findings in scholarly journals and at education conferences.

Participants Rights and Concerns

Please read this consent form carefully and feel free to ask the researcher any questions that you might have about the study. If you have any questions about your rights as a participant in this study, complaints, or adverse events, please contact the

Research Ethics Office at (905) 721-8668 ext. 3693 or at researchethics@ontariotechu.ca.

If you have any questions concerning the research study or experience any discomfort related to the study, please contact the researcher Katlin Walsh at katlin.walsh@ontariotechu.net.

By signing this form you do not give up any of your legal rights against the investigators, sponsor or involved institutions for compensation, nor does this form relieve the investigators, sponsor or involved institutions of their legal and professional responsibilities.

Consent to Participate

1. I have read the consent form and understand the study being described;
2. I have had an opportunity to ask questions and those questions have been answered. I am free to ask questions about the study in the future;
3. I freely consent to participate in the research study, understanding that I may discontinue my participation at any time without penalty. A copy of this consent form has been made available to me.

For the purposes of research, I give consent for (check all that apply)

☐ To be **audio** recorded (i.e microphone on)

☐ To be **video** recorded (i.e webcam on)

☐ To be **neither** audio or video recorded (i.e notes taken)

Study Participant

Print Name	Signature	Date

Researcher

My signature means that I have explained the study to the participant named above. I have answered all their questions.

Print Name	Signature	Date

Appendix C Pre-Study Questionnaire

About You

1. What is your name?
2. What is your gender identity and pronouns?
3. What is your age?
4. What cultural background do you identify with?
5. Do you have any disabilities?
6. What is your job title?
7. What is your educational background?
8. Have you ever been formally trained as a mentor or educator?
    a. If yes, list training, years, and programs mentored.
9. Have you ever been paid to mentor or teach others?
    a. If yes, list the position, years, and program mentored.
10. Have you ever mentored any other STEM programs?
    a. If yes, list the program, years, and program mentored.
11. Have you ever mentored any other youth programs?
    a. If yes, list the position, years, and program mentored.

About your Mentorship

1. What year did you start mentoring?
2. What type of mentor do you identify as? (Teacher, Industry, *FIRST* alumni, Other)
3. What FRC Team Number do you Mentor?
4. In your opinion, how experienced are you at mentoring FRC?
    a. 5-point Likert scale, Beginning to Expert
5. In the last 12 months, how often did you mentor your FRC team?

    a. <10 hours/month, 10-20 hours/month, 20-50 hours/month, 50-100 hours/month, 100+ hours/month

About your *FIRST* Participation

1. Do you, or have you ever volunteered in *FIRST*?
    a. If yes, list the program, roles, and frequency of volunteering
2. Have you ever been recognized or awarded for your contributions to *FIRST*, mentorship, or otherwise (award nomination, special recognition)?
    a. If yes, list the year & type of recognition/nomination.

Appendix D Semi-Structured Interview Questions

1. How did you get involved with *FIRST*? How did you get involved with mentoring?
2. When mentoring:
    a. Are there any specific skills you focus on building? Is there a subteam that you focus on mentoring, or do you mentor more generally?
    b. What is the composition of mentors on the team that you mentor? How many mentors are there?
    c. How do you decide who does what?
3. How did you learn how to mentor? How are you still learning how to mentor?
4. What elements of your identity influence you and your mentorship?
5. Tell me a story of a time:
    a. When you mentored someone with disclosed backgrounds other than your own?
    b. When you mentored someone with disclosed gender identities other than your own?
    c. When you mentored someone with a disclosed disability?
6. What are some factors that you have found contribute to or constrained student engagement when mentoring FRC?
7. How has your approach to mentorship grown or changed since you first started? What factors do you believe influenced that change?
8. What is the most important thing about mentorship to you?
9. What is the least important thing about mentorship to you?
10. How do you see your mentorship or participation in mentorship changing long term?

Appendix E Artifact Request

I'm hoping that you can share artifacts with me that can help to answer *how* you mentor.

Mentorship Tools - Tools that you have used to help you mentor others

- Perhaps a reference poster, slide deck, etc, photos of your notes or calendars
- Focused on team building & culture, business/media-related, or any technical skills development
- You may have created them, or stumbled upon them and decided to use them in your mentorship of others
    - Let me know which

Documentation of Work - Documenting the hard work that you collaborated on with your team, on an individual, or large projects.

- Photo of a project that you helped work on that was particularly memorable.
- Perhaps an essay you helped guide students on with an awards submission, skills training sessions you may have run with new students, progress photos of a robot, or other documentation.

Appendix F Researcher's Sample Mentorship Artifact

2020-2021 Winning Essay Submission: Ontario District Woodie Flowers Finalist Award

"The key to being a good mentor is to help people become more of who they already are; not make them more like you" (Suze Orman). Always encouraging every student's individuality, *FIRST* Alum & lead mentor Katlin Walsh is a stellar example of a mentor who consistently reaches above and beyond. Recognized officially as a *FIRST* Hero by our municipal government, Katlin has taught & inspired students globally to use problem solving skills for the past 9 years.

Katlin dedicates every day to the success of *FIRST* and is an invaluable mentor to its community. She actively supports Canadian FTC & FRC teams on their official slack group and has frequently spoken on '*FIRST* Canada Live' to share tips & stories. She even helped develop resume resources for *FIRST* participants, published in the *FIRST* Alumni Handbook and officially distributed in the 2021 Kit of Parts. As a member of *FIRST* Canada's new Mobile Alumni Crew, she supports & mentors rookie FTC & FRC teams as they build sustainable projects.

Katlin frequently volunteers in every level of *FIRST* and has supported 8 Canadian provinces as a volunteer coordinator, judge, & event manager. She often encourages *FIRST* participants to volunteer at these events, motivating and training them in their new roles. She was awarded the inaugural Ontario FTC Volunteer Appreciation award to recognize her tremendous efforts to help make their first season a success. Even a global pandemic cannot stop Katlin, as she worked to provide more than $20K to low-income & underrepresented *FIRST* teams in Atlantic Canada. In just 6 months, she has helped Eastern Canadians start the first 4 FTC teams in their region & connected 1374 members in a virtual ‘pen pal’ program across Canada.

Katlin expertly explains technical concepts to students while emphasizing the importance of communication & presentation, helping develop well-rounded team members. Last year alone, she mentored more than 15 FLL, FTC, and FRC teams. She recently presented at the inaugural Future of Education Conference about her framework for supporting Girls in STEM through *FIRST*. In 2019, Katlin changed the game by teaching *FIRST* core values & programming fundamentals to 30k students in 5+ countries both in-person & online. Katlin knows how to ‘Make it Loud.’ As a founder of the Robots@CNE off-season, she helped showcase every level of *FIRST* to 70K+ public attendees at North-America’s largest annual fair. She frequently shares her experience with other *FIRST* participants, coaching her students behind the scenes when they presented FRC on National television to 1.2M+ households.

While her immense impact has inspired students worldwide to pursue STEM, Katlin Walsh has taught us here at 1374 to advocate for ourselves, push the boundaries and teach others, all while being gracious and kind. She leads by example and through the guidance she provides as a *FIRST* mentor. Katlin is an outstanding candidate for the Woodie Flowers Award, and 1374 is proud to call her our leader.

Appendix G Coding Scheme for Mentorship Evolution

Refined Codes Related to Participants Mentorship Evolution

Code	Description	Example Quotation
Learning to Mentor (Mentor/Mentee)	Describing learning and teaching fellow mentors through 1:1 mentorship.	"I'm working on sitting back with other technical mentors and having them explain things to me so that I can explain it to students."
Learning to Mentor (Observation)	Describing learning to mentor through observation.	"Mentors are also never asked to take on anything unless they offer it in their first season. That way, they can observe how we mentor."
Learning to Mentor (Prior Experience)	Describing learning to mentor through past experiences.	"I did a lot of mentoring when I was young, late high school, early adulthood. I ran a girl guide company for many years. I tried a lot of things to see what worked. I also took courses in human resource management."
Learning to Mentor (Professional Development)	Describing learning to mentor through participation in professional development.	"I haven't learned too much through *FIRST*'s formal training. They taught me technical skills but not interpersonal skills."
Mentor Background (Industry)	Describing participants' personal experience as a *FIRST* mentor related to recruitment from the professional industry	"Communication is something that's hard to get worse at. Being able to take on the skills that I learned in industry through my day job. Conflict resolution, communication, clear expectations, and apply that to my mentor roles."
Mentor Background (Near-Peer - *FIRST* Alumni)	Describing participants' personal experience as a *FIRST* mentor related to participating on a *FIRST* team for at least one season in high school.	"I had a better understanding [of mentoring] because I knew the process of building robots at that point, and I had the lived experience of building them. It gave me the ability to have coordination during build season, but as

Code	Description	Example Quotation
		a mentor we worked to do what you can and the rest will get done."
Mentor Background (Teacher)	Describing participants' personal experience as a *FIRST* mentor related to a professional background in education.	"The teachers were teachers, they already had the skills to mentor. There was a lot of learning about what to say and how to say it."
Mentorship Style (Leading Facilitation)	Describing a mentorship style that aligns with constructionism where the mentor facilitates, and students take the lead in learning.	"My role was very hands-off. I asked a lot of leading questions to help to get them to the right answer. But I never gave them the answer, I let them chase down rabbit holes [...] because it's a good learning experience."
Mentorship Style (Passive Instruction)	Describing a mentorship style that aligns with instructionism where the mentor serves in an expert instructor role and the students follow a set of steps.	"One of the problems that I ended up having with the team was that the mentors did too much. Too much got done before it was handed off to the students because there were so many mentors that everyone said, 'Oh, I'll do a little bit,' and then a little bit became, 'I'm going to design the full robot, and you students are going to watch the CNC and assemble it.'"

Initial Codes Related to Participants' Mentorship Evolution

Code	Description	Example Quotation
Barrier (Burn Out)	Lack of motivation to mentor due to being overworked.	"A lot of people get burnt out mentoring a team, and they want to stay connected in some way, so they volunteer. "
Barrier (Sustainability)	Lack of motivation to mentor due to team sustainability and resource management concerns.	"Finding mentors is a big issue in terms of sustainability and downtown areas because I just haven't really seen any team successfully keep consistent mentorship in a downtown metropolitan city."
Barrier (Lack of Impact)	Lack of motivation to mentor due to low feeling of having a positive impact.	"After this year. There is very little in me that wants to mentor again, at least in the capacity that I did this year. It was no fun, and everyone was mad at me for stuff, and I also did not get to feel like I had any impact on students, and I said, "This sucks, and I hate it.""
Identity (Personal)	Describing the participant's personal experience.	"I found out about *FIRST* way back when I was in the gifted program in elementary school. We did a robots unit every year, where we used an FLL set without competing"
Identity (Student)	Describing participant's perception of the experiences of students they mentored.	"Student's situations varied widely within a school. Some students were absolutely on free or reduced lunch plans. Before school breakfast, the whole nine yards."
Identity (Team)	Describing the environment and background of the team.	"So our first year, we didn't have tools, and we were building on the lab bench with hacksaws, and one of the team members was actually physically cutting the aluminum. We didn't have any money, so all the pieces we got

Code	Description	Example Quotation
		were from the recycling dump."
Learning (Mentor/Mentee)	Describing learning and teaching fellow mentors through 1:1 mentorship.	"I'm working on sitting back with other technical mentors and having them explain things to me so that I can explain it to students."
Learning (Observation)	Describing learning about how to mentor through observation.	"Mentors are also never asked to take on anything unless they offer it in their first season. That way, they can observe how we mentor."
Learning (Prior Experience)	Describing the application of prior experience to mentorship.	"I did a lot of mentoring when I was young, late high school, early adulthood. I ran a girl guide company for many years. I tried a lot of things to see what worked. I also took courses in human resource management."
Motivator (Peer)	Motivation to mentor due to peers or fellow mentors.	"One of the newer mentors expressed to me that the role that I play in the team is inspiring and that he's seen a shift in the team culture because of my involvement. Hearing that from another mentor and having that respect plays a large role."
Motivator (Personal)	Motivation to mentor due to personal values and goals.	"Wow, I've never felt more included. How do I make other people feel that way?"
Motivator (Student)	Motivation to mentor due to students or youth.	"They're just so young that you see that change, which was amazing and really focusing on how to make these kids better human beings in general, not good at robots."

Appendix H Coding Scheme for Developing The FRC Community

Refined Codes Relations to Participants' FRC Community Development

Code	Description	Example
Authentic Engagement (*FIRST* Program)	Describing authentic engagement to community development at the level of the *FIRST* program.	"To have something that's consistent year after year with an authentic depth of commitment and authentic interest. Something that is not just a Diversity, Equity and Inclusion as a checkmark. Not something that is important for organizational structure check we're doing the right thing. It's genuinely interested in us, and our story is what's been very helpful as a mentor."
Authentic Engagement (Individual)	Describing authentic engagement to community development at the level of the individual mentor.	"I was the first openly queer person on the team. And so, even from the time I was a very early student in the program. It was just what I did. It was a natural transition from student to mentor in that sense. It was just something that all the other mentors knew. If a kid was having a problem or didn't know how to navigate something, I would probably have resources on it. A lot of it's also lived experience."
Authentic Engagement (Team)	Describing authentic engagement to community development at the level of the FRC team.	"A key thing is making sure that your team is intersectional about it. The easiest way not to single someone out is to make sure that the resources and care that you have within your team and your team culture is intersectional. You're not making it just a safe space for one group of people."

Code	Description	Example
Identity & Belonging (Age)	Experienced barriers or support towards FRC community members of diverse age groups.	There are students who graduated that I knew as freshmen, and I cried when they graduated because it felt like, "You are my child now, never mind the fact that I'm six years older than you, you are my child." I still keep in touch with some of those kids.
Identity & Belonging (Disability)	Experienced barriers or support towards FRC community members with invisible or visible disabilities.	"It's something that I'm very used to in a lot of spaces. People forget that I walk a lot slower than them, or they'll forget that I need to be pushed down somewhere in a wheelchair."
Identity & Belonging (Gender & Sexuality)	Experienced barriers or support towards FRC community members who are women, non-binary, or transgender.	"I mean, I remember on (the team I was a technical mentor on) actually was the first time that I saw a trans person mentoring, which I thought was really cool because it's hard to know if that's something that you're allowed to do. I had people in my life say, "They're never going to let you volunteer or mentor students again.""
Identity & Belonging (Social, Cultural & Racial Background)	Experienced barriers or support towards FRC community members of diverse cultural, social, and racial backgrounds.	"My kids get followed by security. They've gone into gas stations to go to the washroom and get snacks and been hassled because they're Indigenous. There's the obvious racism, and then there's the systematic barriers they push against."

Initial Codes Related to Participants' FRC Community Development

Code	Description	Example
Disability (Invisible)	Experienced barriers or support towards FRC community members with invisible disabilities.	"My OCD had gone severe enough that it was impacting my quality of life."
Disability (Visible)	Experienced barriers or support towards FRC community members with visible disabilities.	"It's something that I'm very used to in a lot of spaces. People forget that I walk a lot slower than them, or they'll forget that I need to be pushed down somewhere in a wheelchair."
Gender & Sexuality (Non-Binary)	Experienced barriers or support towards FRC community members who are non-binary.	"Just before competition season, they came out to the team as non-binary, and they picked a different name. The team was super cool with it. That was awesome. I don't think I was ever so proud of a team."
Gender & Sexuality (Transgender)	Experienced barriers or support towards FRC community members who are transgender.	"I mean, I remember on (the team I was a technical mentor on) actually was the first time that I saw a trans person mentoring, which I thought was really cool because it's hard to know if that's something that you're allowed to do. I had people in my life say, "They're never going to let you volunteer or mentor students again.""
Gender & Sexuality (Women)	Experienced barriers or support towards FRC community members who are women.	"Whenever there was a new batch of students who were girls in general, I noticed that they were always more intimidated because they would see a sea of dudes and then say, 'Is robotics a girls' thing?'"
SES (Housing Status)	Experienced barriers or support towards community members with diverse	"I left home at 17. I am still low-income. I was an at-risk youth. A lot of it was that I was around people

Code	Description	Example
	housing statuses.	who were struggling with a lot of things."
SES (Income)	Experienced barriers or support towards community members with diverse income statuses.	"It was such a struggle even getting someone to pick up materials. No one had a car, and no one's parents had a car that they could ask their parents to drive."
Social, Racial, & Cultural Background (Colonial)	Acknowledging reduced barriers or required support for community members as a result of historical colonialism.	"My basic thing is nobody needs another middle-aged white man talking in the room. So as much as possible, my role is to make sure that First Nations youth are doing the talking. So my identity is to be invisible."
Social, Racial, & Cultural Background (Indigenous)	Experienced barriers or support towards FRC community members who are Indigenous	"My kids get followed by security. They've gone into gas stations to go to the washroom and get snacks and been hassled because they're Indigenous. There's the obvious racism, and then there's the systematic barriers they push against."
Style (Individual)	Describing mentorship style as an individual to each student.	"I find my mentorship style is much more tailored to the individual. It's important for me to get to know students to understand what they need."
Style (Proactive)	Describing mentorship style where perceived and potential barriers are removed before FRC community members experience or communicate equity and access issues.	"You have to be intentional about making sure it's a safe space before you push for that representation. You absolutely do want that without tokenizing people. It's not about tokenizing. Naturally, you will get people from lots of groups who are marginalized and underrepresented in STEM."

Code	Description	Example
Style (Reactive)	Describing mentorship style where perceived and potential barriers are removed after FRC community members communicate equity and access issues.	"We had a student in a wheelchair, and it was just a non-issue. In that, we were prepared for it to be an issue, and then it wasn't an issue. We had large plans to build platforms for our machine, but the student didn’t want to build."

Appendix I TCPS 2: CORE Certificate

PANEL ON RESEARCH ETHICS

Navigating the ethics of human research

TCPS 2: CORE

Certificate of Completion

This document certifies that

Katlin Walsh

has completed the Tri-Council Policy Statement:
Ethical Conduct for Research Involving Humans
Course on Research Ethics (TCPS 2: CORE)

Date of Issue: **1 January, 2021**