Beyond Inclusion:
Interrogating the Transformational Potential of Informal STEM Learning

by

Erin Elizabeth Gatz

Bachelor of Arts, University of Waterloo, 2010

Master of Education, University of Toronto, 2013

Submitted to the Graduate Faculty of the

School of Education in partial fulfillment

of the requirements for the degree of

Doctor of Philosophy

University of Pittsburgh

2023

UNIVERSITY OF PITTBURGH

School of Education

This dissertation was presented

by

Erin Elizabeth Gatz

It was defended on

March 14, 2023

and approved by

Cassie Quigley, Associate Professor, Teaching, Learning, and Leading

Hayley Weddle, Assistant Professor, Educational Foundations, Organizations, and Policy

Sarah Fox, Assistant Professor, Human-Computer Interaction, Carnegie Mellon University

Dissertation Advisor: Thomas Akiva, Associate Professor, Health and Human Development

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Makerspaces and education networks are part of the same movement to increase cross-sector collaboration, expand informal STEM learning opportunities, provide professional development, and promote hands-on learning practices. Whereas makerspaces aim to shift power away from instructor-driven pedagogy toward user-centered learning, education networks coordinate learning opportunities and resources throughout a geographic region. In this dissertation, I examine how leaders of makerspaces and education networks grapple with the complexity of intersectionality in attempting to create opportunities for empowerment, skill development, and STEM equity with a particular focus on promoting feminism and anti-racism. In doing so, I examine the possibilities and limitations for how these entities may advance equity in education more broadly, which I understand as supporting culturally sustaining practices and redistributing resources in favor of learners of color, learners with disabilities, girls in STEM, rural learners, and learners in poverty. Chapter 1 explains my motivation for writing this dissertation and outlines the relationship between makerspaces and education networks. Chapter 2 provides an overview of literature on education networks and describes five mechanisms that networks use to achieve their goals. Chapter 3 focuses on a case study of one regional education network and discusses how participation has influenced the work of

members. Chapter 4 examines how a feminist makerspace might be a model for more equitable STEM learning environments. Chapter 5 explores how an ecosystem approach supports informal STEM learning through interviews with feminist makerspace leaders from the United States and Canada. I conclude with the main takeaways from these studies as well as a reflection on what intersectional feminist networks might look like in practice.

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Preface

I am incredibly grateful to my family, friends, and PhD colleagues for their grace and support throughout the last four years. Erik has been the most supportive partner I could ask for by listening to me, offering the best advice, taking care of our children, financially supporting our family, all while working full time and continuing to blossom in his own career. Throughout this degree Eliot has gone from a kindergartener to a third grader, and he has spent many nights sitting next to me on the couch while I do "boring work" on my laptop. Amelia and Henry were the gifts that we did not even know we were capable of creating. I am forever thankful to the nurses and doctors at Magee Women's Hospital for taking such good care of them when I delivered at 30 weeks. My parents and in-laws have been more supportive than I could have ever expected. They all helped Erik and I with countless nights of childcare, groceries, diapers, and emotional support as we grew our family while also working and going to school.

I started this PhD without knowing exactly what I was getting myself into. I knew that I wanted to spend time thinking, reading, and writing about issues that I care about deeply. I did not know that this experience would be the most humbling of my life. The conversations and interactions that I had with other PhD students in the classroom, prior to the COVID-19 pandemic and then during our virtual classes as the physical world shut down, changed how I think about myself and how I engage with others. I am much more cautious about using definitive and causal statements. I am more mindful about speaking from my own personal experiences and to challenge any assumptions that I make about other people. I think carefully about the role that racism, white supremacy, and sexism continue to play in the United States' education system and my own role in both challenging and upholding these systems of

oppression. I understand that I do not have the answers to most questions. I have learned that the best way to understand is to ask questions.

I am fortunate to have had the best advisor that I could have asked for. I first met Tom Akiva in 2017 when I was working full-time as a staff member at the University of Pittsburgh and managing Prototype PGH part-time. He encouraged me to apply for the PhD because he said the questions that I was grappling with would be well suited for the program. He was one of the first people to believe in my capabilities for achieving this degree and he was a constant source of support and motivation for me. I am thankful for the freedom he gave me to pursue my academic interests and to define my own research questions. I am also thankful for the connections he made between me and the incredible team at Remake Learning. Without their support (and infinite patience!) I would not have been able to complete this degree.

Sarah Fox was the best external advisor that I could have asked for. I first met Sarah when she visited Prototype PGH as a postdoctoral researcher at Carnegie Mellon University in 2019. CMU PhD student Yasmine Kotturi introduced us and then Sarah interviewed me about founding a feminist makerspace. When she learned that I was starting a PhD she asked if I would want to co-research with her. As one of the leading scholars on feminist makerspaces and hackerspaces, I was so excited! I worked closely with Sarah over the course of my entire PhD while she and I both balanced the workload of research, work, and parenthood.

I am grateful to Cassie Quigley for opening my eyes to environmental justice in her Freedom Seminar course and to Hayley Weddle for being the most enthusiastic and passionate qualitative researcher I have ever met. Thank you to my mentors Eileen Forrester and Kathy Ellis for helping me to prioritize competing projects so that I could cross this finish line. Significant parts of this dissertation were shaped by the insights and perspectives of Louise Larson, Giselle

Jhunjhnuwala, and Andrea Afua Kwamya. Thank you for trusting me with your voices! I am also grateful to Naomi Chambers for being the inspiration for the last chapter on imagining intersectional feminist networks. I also would not have been able to write this dissertation without the 125+ people who shared their time, energy, and opinions with me. Thank you to everyone who allowed me to interview you as part of this research. I hope that I have done your stories justice.

Finally, I am thankful to my friends who have been so supportive of me and my wild ambitions. The late night dance parties, hang outs in my living room while we played with my kids, meal trains when our twins were in the NICU, and group texts where we commiserate daily, have all been essential for me getting through this program.

1.0 Introduction and Dissertation Overview

Inequity is the defining issue in education today, and systemic discrimination based on race, gender, class, ability, and geographic location is a driving force (Schmelkes, 2020). Compounding these systemic inequities in education is the reality that educators often work in isolation and feel unsupported in their profession (Ostovar-Nameghi & Sheikhahmadi, 2016). However, cross-sector collaboration in the form of coalitions, networks, and mutual aid might provide educators and learners who are most directly impacted by injustice to create structures for community that allow for autonomy and control. In fact, existing research—though limited—demonstrates that the impact of collaboration on educators' experiences can include decreased isolation, the development of supportive relationships, and capacity building (Weddle, 2022). Additionally, making STEAM learning relevant to student interests has been shown to meaningfully engage learners by designing problem-based curricula, rooting scenarios within real-world issues, and drawing on students' interests in digital technology as part of the problem-solving process (Quigley, 2017).

As such, throughout this dissertation I assert that feminist makerspaces and education networks have the transformational potential to create systemic change through cross-sector collaboration by expanding informal STEM learning opportunities for marginalized communities, shifting power away from instructor-driven pedagogy toward user-centered learning, and coordinating learning opportunities and resources more equitably throughout a geographic region.[1] In this context, I understand feminism as the practice of centering the

[1] I provide definitions of makerspaces and feminist makerspaces later in the dissertation. However, it is important to note that the term "makerspaces" originated from a largely white, male, Eurocentric perspective and that feminist makerspaces work to reclaim the rich, global history of women in making, crafting, coding, and engineering.

experiences of women, with a particular focus on uplifting women of color and trans women, in education. I understand anti-racism as the practice of supporting policies that address racial inequities through actions and ideas (Kendi, 2019).

I became interested in makerspaces and education networks nearly ten years ago when I learned about a part-time afterschool STEM instructor position with a Pittsburgh-based education network. After applying and being accepted for the position, I was provided with several weeks of training in basic robotics, computer programming in JavaScript and HTML, and electronics design. Following this introductory training, I then worked in several after school programs based out of libraries, community centers, and schools throughout the city. I loved the collaborative and creative nature of the work. At Woolslair Elementary, we created electronic circuits, tested the conductivity of materials like bananas, Play-Doh, and even the human body, and then we created musical instruments out of these materials using computer software. At the Jeron X. Grayson Community Center and at Arsenal Elementary, we learned how to create video games in Scratch through block chain coding in JavaScript. At the Carnegie Library and The Pittsburgh Project community center, we learned how to 'hack' the front page of *The New York Times* website by inspecting its source code and editing it locally through HTML. One student hacked the front page of the website to read: '*Local Pittsburgh Student Wins U.S. Presidential Election!'* Students were engaged, having fun, and learning. And so was I.

Through this program, I was hired for a full-time job as a STEM youth educator at a local makerspace. I developed curriculum and engaged young learners in summer camps, after school programs, and family maker nights. In these programs, I taught students how to create designs for computer numerical control (CNC) equipment such as laser cutters and wood routers, CNC vinyl cut for heat press onto fabric, 3D print and model with computer aided design software,

weld and cut sheet metal, screen print, and solder circuit boards to make wrist watches and radios. I found that working outside of the formal K-12 setting allowed for a lot of flexibility with the curriculum and that students could learn in a project-based way with their own goals in mind. I started most programs with an introduction to the engineering design process, asking students, "What is a problem that you face in your everyday life? Now let's prototype solutions to that problem!" This question yielded many creative projects over the years, ranging from an LED bow tie sewn with conductive thread (the Allerdice High School student who invented it won best dressed at prom) to an earring line featuring student names that were laser cut from acrylic (the Westinghouse High School student who invented them sold dozens of pairs throughout summer camp).

In both the makerspace as well as the education network, however, there were two main aspects of the work that troubled me. First, I worried about the sustainability of programs that aimed to teach students STEM skills while relying on extremely part-time educators who worked as independent contracts for short-term and grant-funded programs. Second, the adult instructors in these spaces were often predominantly white and male - they did not reflect the communities that youth were coming from. Although the makerspace and the education network received significant grant funding to support the participation of low-income students in the programs, I questioned whether this was a systemic or long-term approach to creating equity in education. I imagined what it would look like for low-income students city-wide to have free, long-term, and widespread access to cutting edge technology and software, and to work alongside caring adults who come from their communities. I also wondered how to create curriculum informed by feminist and culturally relevant pedagogies that would support and validate the experiences of students who are traditionally marginalized in STEM.

In this dissertation, I assert that makerspaces and education networks are *part of the same movement* and that both entities struggle with similar challenges while also having the potential to increase opportunities to engage in equitable learning experiences as shown in Figure 1 below. Both movements facilitate informal STEM learning experiences and offer professional development as well as collaborative opportunities for hands-on learning. While makerspaces aim to shift the power away from instructor-driven pedagogy toward user centered learning, education networks focus on distributing opportunities and resources equitably throughout a geographic region. Viewing makerspaces and education networks as part of the same movement helps educators and researchers understand the possibilities and limitations for how these entities can advance equity in education, which I understand as redistributing resources in favor of learners of color, learners with disabilities, girls in STEM, rural learners, and learners in poverty.

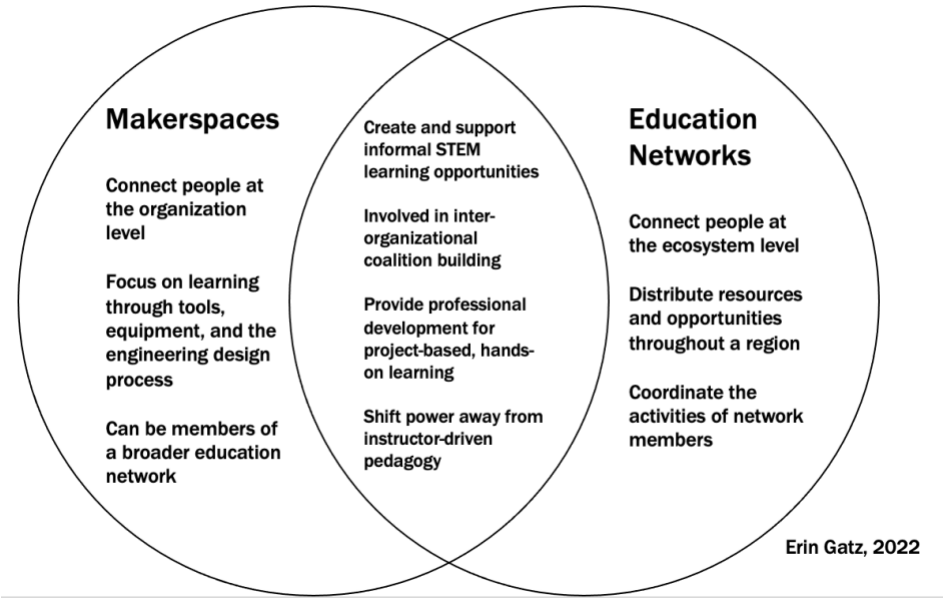

Figure 1 Venn Diagram of Makerspaces and Education Networks

For these reasons, I examine the following research questions throughout this dissertation: 1) How do makerspace participants see racial justice and gender equity reflected in the activities of the space? 2) What are the specific mechanisms by which education networks aim to advance equity in education? 3) How does an ecosystem approach ensure the longevity of informal STEM learning spaces?

In Chapter 2, I provide an overview of education networks, summarize relevant literature on networks in adjacent fields, and describe five mechanisms that networks use to achieve their goals. In Chapter 3, I focus on a case study of one regional education network and explore the themes that arose from interviewing 111 members about how participation has influenced their work. In Chapter 4, I focus on a case study of one feminist makerspace and I examine how participants have worked to build coalitions, seek autonomy from corporate influence, and center racial justice in their work. In Chapter 5, I examine the practices of 17 participants representing nine feminist makerspaces to sustain their spaces. I find that when an ecosystem approach is enacted – deepening existing relationships in local communities, building coalitions, and creating counter-institutions with other social justice organizations – the long-term sustainability of these spaces is strengthened. In doing so, I offer a potential path forward for informal STEM learning spaces. In Chapter 6, I conclude with the main takeaways from these studies and I explore what intersectional feminist networks might look like in practice.

1.1 A Note on Methods

Throughout this dissertation, I employ retrospective autoethnography, using my experiences of co-founding a feminist makerspace and working for a regional education network to reflect on how such entities might be models for more equitable informal STEM learning environments. As Bell et al. (2019) argue, "autoethnography must of necessity be a generative and enabling frame for mining the possibilities borne of our defiant dreams" (p. 9). I intend to use my own experiences as an object of study and a source of knowledge. I also hope to interrupt the widespread phenomena of what Kincheloe & Tobin (2015) describe as, "Western researchers and those they have influenced around the world [having] difficulty appreciating their own temporal location" (p. 522). In an effort to appreciate my own location and to triangulate my findings, I use various methodologies such as interviews, case studies, literature reviews, and autoethnography throughout this dissertation to increase the rigor of my work. For example, in Chapter 2, I employ a literature review to examine what is known about how networks achieve their goals. In Chapter 3, I use the case study method to explore how a regional education network affects its members. In Chapter 4, I employ retrospective autoethnography which allows me to use my own experience of co-founding a feminist makerspace to provide insight into the possibilities for these spaces to promote racial justice and gender equity in education. Finally, in Chapter 5, I draw from international interviews with feminist makerspace founders and participants which allows me to investigate the shared challenges and opportunities that these spaces encounter throughout their evolution. Taken together, the diverse methods that I use throughout this dissertation allow me to explore the affordances of subjectivity and autoethnography in research and offer potential paths forward for other research-practitioners.

2.0 How Can Education Networks Advance Equity?

2.1 Introduction

Learning occurs across the human lifespan and across formal and informal settings such as schools, community centers, makerspaces, and at home. Although the lifelong and lifewide nature of learning is well understood, less is known about the nature and power of collaboration and coordination among the people, projects, and organizations working to facilitate equitable learning experiences. Education networks and coordinating organizations are widespread around the world, yet they are seemingly invisible in educational research. In this chapter, I explore the degree to which education networks might advance equity across learning environments. The first part of this chapter defines what education networks are and provides examples of what they look like in practice. The second part provides a literature review of network organizations, networked improvement communities, out-of-school-time (OST) intermediaries, and collective impact initiatives. As a result of this literature review, I find five main mechanisms that education networks use to advance their goals. These five mechanisms are: 1) Identify the domain(s) in which the network operates; 2) Reach an agreement among members about shared values for their collective action; 3) Build inter-organizational trust; 4) Redistribute resources to isolated nodes, and; 5) Maintain strong connections among members. I explore each of these findings more deeply throughout the literature review.

2.2 What is an Education Network?

Education networks can be understood as intermediary organizations that facilitate cross-sector collaboration among the out-of-school time, higher education, K-12 sectors, as well as any sector where people have a stake in learning. Examples of regional education networks in the U.S. include the Remake Learning network in Pittsburgh, the Chicago Learning Exchange, and Hive New York City. Remake Learning works to bring educators, technologists, government, and non-profit leaders together to collaborate and share knowledge about how to make learning more equitable, engaging, and relevant. Similarly, the Chicago Learning Exchange aims to increase participation in Chicago's out-of-school time ecosystem, with a focus on equity, innovation, impact, community, and collaboration. The mission of Hive NYC is to transform education by making connected learning central to the practices of educators and organizations. This includes encouraging educators to adopt connected learning practices and teach web literacy, creating high quality connected learning and web literacy tools and curriculum, and funding schools and youth programs to provide learning and web literacy programs especially in under-served communities. It is important to note that across each of these regional education networks, there is a commitment to furthering connected learning, which can be understood as a young person having the opportunity to pursue a personal interest and passion with friends and caring adults in ways that are linked to academic achievements, career success, or civic engagement (Ito et al., 2013). In the following table, I provide a sampling of education networks worldwide to illustrate a broader picture of the activities that education networks are involved in. Most education networks provide cross-sector collaboration, professional development, and networking events while documenting and communicating the successes that result from these

collaborations. However, only a few education networks offer grant funding to catalyze and sustain community-led projects.

Table 1 Examples of the Activities and Geographic Spread of Education Networks

Education Network	Location	Description
Remake Learning	Pittsburgh, U.S.	An open group of educators and innovators with a mission to make learning more engaging, relevant, and equitable for young people through grants, communications, and networking opportunities.
Hive Learning Network NYC	New York City, U.S.	A collective of peer-to-peer educators, activists, artists, and technologists representing 30+ organizations with a mission to empower learners as co-designers and build digital equity for youth.
Chicago Learning Exchange	Chicago, U.S.	A team of learning scientists, educators, and community leaders with a mission to support racial equity, access, and quality in the Chicago out-of-school time ecosystem.
Community Share	Tucson, U.S.	A group of educators, entrepreneurs, ecologists, artists, nonprofit organizations with a mission to create real-world learning experiences that contribute to resilient, thriving youth and communities.
The Learning Collaborative	Kansas City, U.S.	A network of museums of community institutions that promotes civic learning through communication and collaboration among students, teachers, and educators.
Nova Escola	Brazil	A nonprofit organization with a mission to improve education in Brazil through a free platform for educators to engage in digital and in-person courses on national learning standards implementation.
TeachAThon Edtech Network	Nigeria	The Edtech Network evolved from an in-person and online Teach-a-Thon for educators to learn how to adopt and integrate technology into their classrooms.
Weaving Lab	Holland	A community of system change practitioners working together to interconnect people, projects, and places to form thriving systems.
Learnlife	Spain	An open ecosystem to promote lifelong learning among educators, learners, and government through afterschool programs and summer camp.
Cities of Learning	England	A digital badging program to help cities and regions design and deliver inclusive, lifelong learning by building the skills needed for people, employers, and communities to thrive.

Learning City	New Zealand	A collective that connects community members to existing learning opportunities in Christchurch through an online directory of participating organizations.
Education City	Qatar	A physical campus with international universities, start-up incubators, technology parks, heritage sites, and cultural institutions.

Note: Descriptions drawn from organizational websites.

2.3 Research Questions

Although education networks hold much promise in their pursuit of facilitating cross-sector collaboration, less is understood about the mechanisms by which they aim to create more equitable learning environments. As such, the purpose of this literature review is to explore what education networks may be able to achieve in their pursuit of advancing equity. Specifically, I address the following questions: 1) To what degree can education networks advance equity (understood as redistributing resources in favor of the most marginalized learners and educators) and; 2) What does existing research tell us about the mechanisms by which education networks advance equity? Examining the literature surrounding these questions might help researchers and educators understand what education networks can achieve in their pursuit of advancing equitable learning environments and systems.

2.4 Methods for Literature Selection and Review

To select the articles for this review, I conducted a search with the key words, “collective impact”, “education networks”, “networked improvement communities”, and “OST intermediaries.” As shown in Table 2, I reviewed the results from this search and then selected articles that specifically address how these entities aim to achieve their goals. With a focus on

my research questions, I then summarized the primary mechanisms that networks use to achieve their goals.

Table 2 Keyword Search Results for Literature Review

Keywords	# Initial Results for Keywords	# Results for Keywords + Equity
Collective impact	35,700	10,500
Education networks	13,200	2,750
Networked improvement communities	1,200	618
OST intermediaries	25	8

2.5 Literature Review: Five Mechanisms of Networks

2.5.1 Mechanism 1: Identify the Domain(s) in Which the Network Operates

To organize the literature review, I use five mechanisms which draw largely from De Lima's 2010 work on networks. One of the most important steps a network must take is identifying the domain(s) in which it operates. De Lima also calls for researchers to define their terms carefully. He argues that the use of the network concept has been too subjective, vague, and trendy and that a more scientific, rigorous, and objective approach must be taken by researchers and policymakers to understand the possible benefits of networks. Importantly, De Lima calls attention to the reality that:

> With notable exceptions…scholarly writing on educational networks has tended to focus almost exclusively on how good networks are and how much more we need to invest in them. However, there is nothing inherently positive or negative about a network: it can be flexible and organic, or rigid and bureaucratic; it can be liberating and empowering, or stifling and inhibiting; it can be democratic, but it may also be dominated by particular interests (p. 2).

According to De Lima, differentiating between the many types of inter-organizational networks in education is the first step toward understanding what education networks actually do as well as what they are capable of doing. The various network organizations that currently exist include a wide range of self-described alliances, coalitions, collaborations, clusters, consortia, development groups, families, partnerships, federations, groupings, territories, trusts, and zones (De Lima, 2010). De Lima reminds us that each word comes with its own history and that educators should be mindful when describing the type of interorganizational effort they are a part of. De Lima further argues that "most of the times, the term 'network' is used normatively to advocate what organizations must become, rather than to describe what they *are*" (p. 3).

There are two popular conceptions of what a network is, according to De Lima, and neither of them do the term enough justice. The first conception is of a network as a broad organizational template for non-hierarchical working relationships, which cut across intra- and inter- organizational boundaries (De Lima citing Nohria and Eccles, 1992). The second conception is a network as a technological system that enables fluid and flexible interconnections among actors located in different intra- and inter- organizational levels and sectors. De Lima argues that according to these definitions, any organization can be considered a network if we understand hierarchy as simply "a centralized network in which the vast majority of ties flow to or from one particular node" (De Lima citing Podolny and Page, 1998).

Although the members of a given education network might view it as being open, free, accessible, and non-hierarchical, the reality might be quite different for individual or organizational actors in the region who are not actively involved in the activities of the network or who do not know how to get involved. For example, while many education networks describe themselves as emergent grassroots movements, the reality is that foundations and private sector

actors are often responsible for spearheading their creation as well as supporting their ongoing operations. Who 'owns' a network is an important question because it influences why people participate. An educator might join a network that was founded by a philanthropic initiative because they want to gain access to social capital or financial resources. Other reasons that educators might join a network is to learn from others, lobby collectively, or simply to celebrate and feel validated in their chosen profession.

In addition to perceived network ownership and member motivations for joining, the purpose of a network is also key. Whereas multi-purpose networks might be less effective in achieving their intended goals, a narrow and focused network might leave many issues seen as 'fringe' unaddressed (De Lima, 2010). In the case of the three regional education networks that I introduced earlier: CLX, Remake Learning, and Hive NYC, one might understand their missions to be multi-purpose so as to allow for a broad and evolving purpose that attracts many different kinds of stakeholders that likely disagree on important issues in education but that can generally agree on supporting young people in their interests and development.

Collective impact initiatives take a more targeted approach to addressing systemic inequities by naming specific problems and identifying the actors needed to solve those problems (Kania & Kramer, 2021). An example of what this could look like in practice are networked improvement communities (NIC), which take a systems-level approach to addressing inequities in education. Bryk et al., (2011) state that NICs are involved in asking: 1) What problem(s) are we trying to solve? 2) Whose expertise is needed to solve these problems? 3) What are the social arrangements that will enable this work? Addressing low graduation rates, for example, takes a broad coalition of stakeholders from school counselors to parents and school administrators to out-of-school time educators. As such, NICs are an effort to organize the diverse expertise

needed to address educational inequities and problems by facilitating the exchange of information across sectors. Other examples of NICs include the International Technology Roadmap for Semiconductors which coordinates innovation efforts in the microelectronics industry, the Institute for Healthcare Improvement which seeks to improve global healthcare outcomes, and an education NIC which seeks to address failure rates in community colleges.

2.5.2 Mechanism 2: Build Inter-Organizational Trust

Building trust among various people across organizations through informal networks is another powerful way to work toward collective goals. In one of the earliest papers written on informal networks by Krackhardt and Stern at Cornell University in 1988, the authors argue that organizations with a particular social network structure are more effective than most organizations in responding to crises. To reach this conclusion, the authors conducted an experimental simulation in which two organizations were designed to be comparable in every way except for the arrangement of friendships among employees. In one organization (the 'optimal' organization), the number of friendships between separate departments of the organization was maximized while the number of friendships within a particular department was minimized. In the second organization (the 'natural' organization), the number of friendships within a department was maximized while the number of friendships between separate departments was minimized. Participants then played a game in which they were presented with organizational tasks such as gathering and disseminating information, filling out forms, or allocating resources. The researchers found that the optimal organization out-performed the natural organization because efforts at inter-departmental cooperation resulted where friendship extended across departments. In other words, friendships produced cooperation but only when

those friendships extended beyond single departments. In the natural group, where friendships were more concentrated within a single department, inter-departmental networks of trust were lacking which led to less cooperation and inability to meet organizational goals. Finally, the researchers found that in groups where there is inter-departmental trust and friendship, groups were able to raise performance indicators and solve unexpected problems at a faster rate than in groups where there was little inter-departmental trust and friendship. While this would be a difficult experiment to test out in the context of education networks, it does raise the question: What it would look like if members of a particular regional education network were faced with a series of tasks that required trust, relationships, and awareness of systemic inequities, compared with a group of educators who were not network members and who operated in a silo? More specifically, does advancing equity in education depend on the strength of cross-sector, inter-organizational friendships, and trust?

2.5.3 Mechanism 3: Reach an Agreement Among Members About Shared Values for Their Collective Action

Establishing shared values and reaching an agreement among network members is another key mechanism that networks employ to reach their goals. Although some entities have been on the forefront of scaling education networks worldwide, there has arguably been little work to establish shared values. The Finland-based group HundrED has the stated goal according to their 2020 report *Development of an Innovation-Friendly Education System* of being "the world's leading expert in innovations which improve education and assist all children worldwide in receiving education in the way that suits them best" (p. 9). As part of this mission, HundrED

assesses education innovations across the world and each year issues awards to collaborative efforts that improve education. Criteria used to assess these efforts falls into two main categories: scalability and effectiveness of innovation. If an innovative initiative is impactful but not scalable, not impactful and not scalable, or impactful but not scalable, then it is not seen as successful. However, innovative initiatives that are seen as both impactful and scalable are given recognition and financial support by the HundrED organization. Ideologically, what HundrED relies on to acknowledge and scale education innovations is American sociologist Everett M. Roger's "Diffusion of Innovation" (p. 17). Key to this theory is that people considering the adoption of innovative practices will be more likely to listen to the advice and experiences of colleagues than on objective or scientific knowledge. As such, HundrED targets innovative initiatives that are in the earlier stages in order to provide encouragement and support which increases the likelihood that it will be successfully implemented in its context and scale.

However, HundrED does not explicitly name equity as a core value of its mission or as being an important feature of the projects that it seeks to elevate. In fact, throughout the 90-page document that HundrED compiled to feature various organizations that employ innovative learning practices throughout the world, the word "equity" only appears once and it is with reference to the importance of seeking venture capital and equity in the early stages of innovation. Interestingly, neither "gender" nor "race" appears throughout the report which raises important questions about whether the innovations being considered for elevation and celebration are in fact increasing equity and access for marginalized communities.

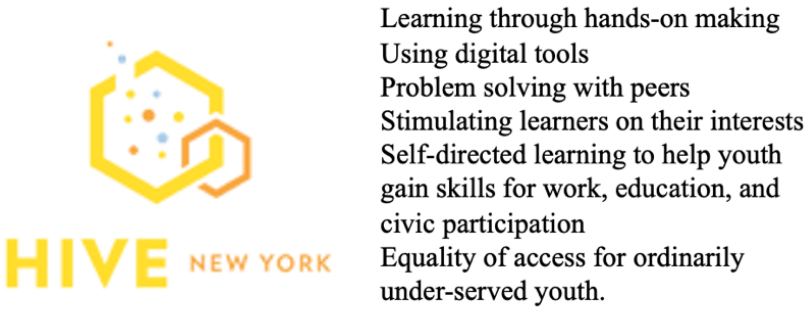

Figure 2 Education Network Profile: Hive NYC

In the context of our three education network profiles, CLX and Remake Learning both seem to operate from a value system that identifies systemic racism as the main problem in education. However, it is less clear that Hive NYC operated from this assumption based on the language around 'equality of access' in its mission statement, as shown in the above Figure 2. Reaching an agreement among members about their shared values and the collective action that should be taken based on these values, is a crucial mechanism for networks.

2.5.4 Mechanism 4: Redistribute Resources to Isolated Nodes

One of the most important aspects of education networks is that many of them aim to redistribute resources in a more equitable way than current systems allow, particularly by addressing a growing gap in who has access to quality education. The 2018 report *Research Foundations for the Chicago Learning Exchange* highlights the growing gap between wealthy families and poor families in the United States when it comes to how much money parents spend on extracurricular activities for their children. According to a 2012 study by Bennett et al. cited in the report, wealthy families spend 11 times more on extracurricular activities than poor families, and this number has risen drastically since the 1970s (Larson et al., 2018). The reason

this is cause for concern is that youth from poor economic backgrounds are not getting access to the same high quality in-school or out-of-school time programs as their affluent peers. This report by Chicago Learning Exchange (CLX) finds several gaps when it comes to youth engagement and awareness of OST activities. These gaps include: awareness of learning experiences, transportation and access costs, attendance (youth might have access and awareness to high quality programs but not feel welcomed in these spaces and stop attending), engagement (youth may participate but not be deeply engaged if programs do not relate to their interests or identities), learning pathways (educators acting as mentors and connecting youth to further programs), and opportunity (no clear outcome for future career or interest driven hobbies).

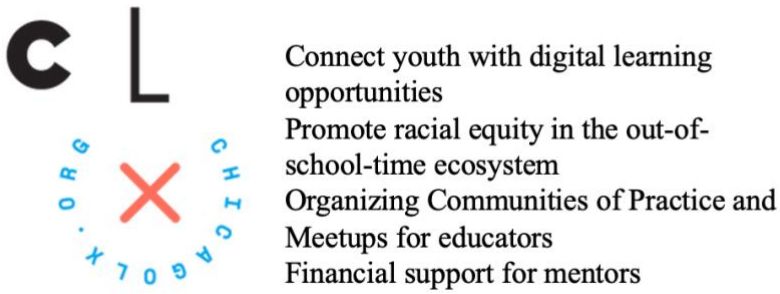

Figure 3 Education Network Profile: CLX

As shown in the above Figure 3, the specific strategies that CLX uses to promote connected learning and address these equity gaps include: 1) Financial support for mentors, 2) Cultivating a professional learning community of peers, and 3) Fostering learning pathways and issuing digital badges that recognize OST achievements. CLX acknowledges that learning experiences are not equitably distributed across society and for this reason, it works to center racial justice in its support in the out-of-school-time ecosystem. According to Larson et al. (2018), CLX focuses on providing support to educators that work with youth who are

"economically challenged" – to connect youth with caring adults and mentors and create clear trajectories for "real world pathways" (p. 10).

2.5.5 Mechanism 5: Maintain Strong Connections Among Members

Each of the mechanisms that I have discussed so far are used to varying degrees in education networks, networked improvement communities, and OST intermediaries to affect equitable change in education. The last network mechanism I discovered is maintaining strong connections among members, which is particularly prevalent in learning ecosystems literature. Hecht and Crowley (2019) describe learning ecosystems as, "a constellation of intertwined and entangled elements, where learning happens through dynamic relational processes among the people, places, and stuff we find across/within/between school and out-of-school places" (p. 269). In other words, learning happens both within and beyond the walls of schools and throughout a person's lifetime, and educators can help to 'connect the dots' for learners between formal learning experiences and learning that occurs in out-of-school settings. Understanding education networks and OST intermediaries, within the context of learning ecosystems is important because both entities are involved in the management of ecosystems. Akiva et al. (2020) propose that realizing the promise of learning ecosystem approaches requires: 1) Broader views of what is valued as learning, what learning spaces are considered legitimate, and who is "deserving" of learning opportunities, and 2) Expanded notions of adult leader expertise for supporting learning and development. Doing so uplifts the work of OST educators and recognizes the many places where learning occurs.

A recent example of how learning ecosystems can maintain strong connections among members and uplift OST educators is an initiative to map the organizations involved in the Pittsburgh literacy ecosystem. In the 2021 report *Mapping the Organizations in Allegheny County's Literacy Ecosystem*, Orman interviewed a team of families, community members, professionals, and scholars who are committed to ensuring that students in kindergarten through third grade in the Allegheny County of Pittsburgh have access to culturally affirming reading material that supports racial equity and positive relationships between youth and adults. As part of these interviews, Orman sought to understand the organizational network that supports literacy in our regional literacy ecosystem. Orman notes ecosystems are complex and that they are comprised by many overlapping networks that are constantly changing. Even so, it is possible to map out parts of an ecosystem by drawing artificial boundaries and focusing on a particular set of organizations, people, or projects that are doing similar work. Orman offers the following key considerations when doing ecosystem mapping: 1) Identify who is in the network by asking participants to identify key actors, 2) Explore what the network looks like in terms of its underlying structure, density, and connections, and 3) Engage with network members to think about the networks they are embedded in and the relationships they have formed.

In terms of how this mapping activity can help networks to maintain strong connections among members, there are a few main takeaways. First, in a particular regional learning ecosystem we might hope that organizations are all connected either through intentional collaboration or general awareness of the other organizations' activities. Second, visualizing the relationships between organizations doing similar work within a particular network might allow for leaders of these organizations to maximize impact in the services they offer by understanding where they overlap with other organizations and by focusing on the services that they are

uniquely suited to provide. Mapping connections in an ecosystem also helps researchers and evaluators understand what the impact of networks is on educators and the learners they serve.

For example, based on this literacy ecosystem mapping project, Orman found that most organizations are involved in relationships with other organizations because of the acquisition of resources such as money, materials, services, people, knowledge, and space. In other words, one-way interactions that serve to benefit the receiving organization. This helps us to understand what organizations are seen as power brokers in the network and the nature of their relationship with other organizations. Importantly, mapping ecosystems can also help to identify which organizations are isolated nodes. This is particularly important for education networks that have equity as a core value. If an education network aims to advance equity in education but several organizations are isolated nodes on the map, then this can serve as a powerful visual reminder that not all organizations have equal access let alone equitable participation in network activities. If the goal is to advance equity in education, then one of the specific mechanisms that an education network might employ is mapping the actors and relationships in that ecosystem.

Interestingly, Orman suggests that Pittsburgh might consider hiring an "ecosystem manager" to organize and coordinate literacy activities and leverage cross-organizational efforts. The manager would not direct the ecosystem, but would instead act as a facilitator in creating shared goals and a common agenda across the various literacy organizations in the region. Mapping would therefore also help this manager to identify where collaborations exist, where there is potential to support isolated organizations, and where there might be commonalities in visions across organizations.

Using a learning ecosystem framework to visualize and strengthen relationships across settings is a growing trend around the world (Hannon et al., 2019). One of the leading

organizations involved in uplifting awareness of learning ecosystems is the World Innovation Summit for Educators (WISE), a forum started by the Qatar Foundation. According to the criteria used by WISE to assess whether a particular initiative is a learning ecosystem, it should have the following features: 1) diversify learning resources and pathways for learners; 2) activate and share resources for learning in new ways; 3) be dynamic in composition; 4) be supported by infrastructure; 5) comprise formal and informal learning institutions; 6) have distributed governance; 7) be learner driven, and; 8) meet 21st century challenges beyond academic attainment. As shown in the below Figure 4, Remake Learning might constitute a learning ecosystem according to the WISE criteria:

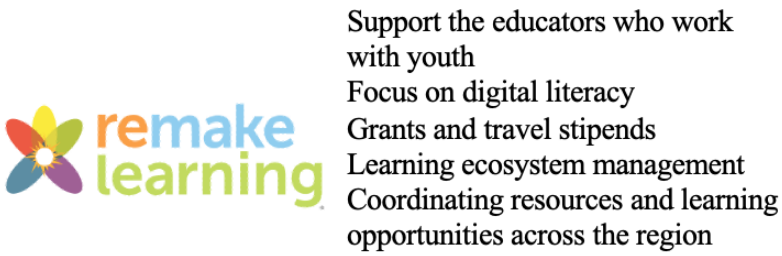

Figure 4 Education Network Profile: Remake Learning

2.6 Discussion

As I have explored throughout this chapter, education networks are widespread entities that promote broader ideas around what constitutes learning. These ideas include interest development, persistence in learning, civic participation, and development of a positive sense of the future (Ito et al., 2020). Education networks have also played a significant role in shifting the conversation away from typical educational success outcomes such as standardized test scores, attendance, grades, or graduation rates.

However, research also shows that funding from sources outside the formal publicly funded education system have been necessary for creating education networks. This raises important questions about the sustainability of education networks once initial funders have pulled their support. It also remains to be seen whether education networks that do not provide paid incentives are attractive entities for educators to join. In examining the mechanisms by which CLX and Remake Learning aim to advance equity in education and looking to the three pillars of network evaluation (Taylor et. al, 2014), it seems that network connectivity is strong and that it is primarily fostered through working groups, networking events, and professional development opportunities. Network health appears to be strong for both CLX and Remake Learning as resources and infrastructure are currently provided through substantial grant funding from leading philanthropists in Chicago and Pittsburgh. Finally, in terms of the outcomes achieved toward a desired goal, this is where the results are less known. In both the case of CLX and Remake Learning, it is unclear whether there is a specific goal or intended impact to be achieved as in the adoption of a particular policy, practice, or change in community members.

Learning ecosystems as a theoretical lens helps us to see that education is not only the business of schools and teachers, and that non-educators might take on roles in support of learning, such as caring adults engaging in mentorship roles. This approach promotes a broader view of what is valued as learning, what learning spaces are considered legitimate, who is 'deserving' of learning opportunities, and expanded notions of adult leader expertise for supporting learning and development (Akiva, 2021). Furthermore, the process of mapping learning ecosystems can help educators and researchers visualize the relationships between organizations doing similar work, which can facilitate collaboration and maximize impact in services.

2.7 Conclusion

Throughout this chapter I have worked to uncover what is known about the nature and power of collaboration and coordination among the people, projects, and organizations working to facilitate equitable learning experiences. By exploring the literature on education networks and adjacent fields, I have found that in the context of CLX, Remake Learning, and Hive NYC, some work has been done to map the number of network participants and the industries in which they work, particularly through online network member directories. However, it is unclear whether this is a widespread practice across education networks. Furthermore, while CLX and Remake Learning both seem to operate from a value system that identifies systemic racism as the main problem in education, it is less clear that Hive NYC operated from this assumption based on the language around 'equality of access' in its mission statement. In each of the three education networks in this chapter, I have found a lack of agreement among networks with regard to the fundamental meaning of their collective action. As I stated earlier in this chapter, this lack of agreement seems to be a key missing piece in the education network movement.

Furthermore, my research also raises questions about whose responsibility it is to redistribute resources and opportunities in a way that benefits the most marginalized people in society. Is it the non-profit community, philanthropists, government, individual educators working alone, or collectives of concerned stakeholders? Based on the literature that I have reviewed, it is evident that a systems-level change is necessary for fundamentally improving education to become more equitable. Part of this systems-level change might involve the participation of education networks, learning ecosystems, collective impact initiatives, and

networked improvement communities. However, regional education networks should reach an agreement among their members about what the problem is, whose expertise is needed to solve it, and what social arrangements will enable the work. If education networks can identify goals at the individual, organizational, and systems levels, and then collect data to assess progress toward these goals, then there is potential for these entities to advance equity in education.

3.0 The Role of Professional Networks for Formal and Informal Educators

3.1 Introduction: Why Education Networks?

Over the last decade, regional education networks comprised of nonprofit organizations, schools, libraries, museums, and individuals have become important entities, focused on creating equitable education policy, professional development, and student learning (Riehl et al, 2019). These cross-sector networks are typically managed or curated by backbone organizations such as Intermediate Units, United Ways, school districts, or by stand-alone independent organizations (Kania & Kramer, 2011). The purpose of these network-focused organizations is to build collaboration across sectors, often in the form of working groups, networking events, and professional training for educators (Riehl et al, 2019). With the ongoing pandemic of COVID-19 exacerbating and making visible existing educational inequities, now is a particularly important time to understand the role of networks in supporting educators and centering issues of equity.

To contextualize how networks fit within the broader education system and their potential role in efforts to reduce inequities, I begin with a review of relevant theories including learning ecosystems, legitimate peripheral participation, professional identity, and communities of practice. I then introduce a U.S. based education network, as a case in which to situate this study, and provide a look into its formation and evolving mission. Through interviewing educators with various levels of network engagement, I ask two research questions: 1) What influence does participation in the network have on educators? 2) Does network participation influence individuals differently, depending on their level of involvement?

It is my hope that the findings of this research may help other education networks understand how ideas about equitable education circulate, as well as the role of such entities in

supporting the professional identity development of educators. Specifically, I explore the ways in which education networks might help to achieve more equity in education by turning the focus to educators themselves. Through this phenomenological case study (Patton, 2015), I find that education networks might influence participating individuals in the following ways: 1) celebrating and validating their profession as educators, 2) promoting networking and relationship building in a profession that otherwise tends to be done in isolation, and 3) circulating ideas about equitable learning practices. These three focal areas are the main themes that emerged from my analysis of network member interviews.

3.1.1 Learning Ecosystems, Networks, and Network Organizations

To consider the role of education networks and network organizations in formal and informal education, I take a learning ecosystem perspective (Akiva, Hecht, & Blyth, in press). Within this context, education network organizations, referred to as backbone organizations (e.g., Kania & Kramer, 2011) or intermediary organizations (e.g., Donner & Little, in press), can be seen as taking on a role of convening, networking, coordinating, and facilitating in order to promote new ideas and build structures for change (McAdam, McCarthy, & Zald, 1996) - in other words, intentionally shaping learning ecosystems. Structures for shaping and managing ecosystems might take the form of local organizing committees, professional development sessions or conferences in which informal and formal educators come together to discuss and act on important issues facing education. Supported by a backbone or intermediary organization that acts as a facilitator, network convenings may serve a “bridging function” between local

neighborhoods and public officials, connecting residents and educators with the necessary resources to advance their goals.

Whether led by a backbone organization or less centrally organized, education networks are dynamic and complex. Working groups within a network, for example, may be member-led, with evolving agendas, which can create non-linear, emergent paths that make it difficult to chart outcomes from a research and evaluation perspective. As Jacobson et al. (2019) note, complex educational systems "have nonlinear properties, which cannot be analyzed by adding up the parts because the patterns at the macro-level of a complex system generally have different properties to the constituent parts at the micro-level of the system" (p. 114). Measuring the collective impact of education networks is therefore a complex task that does not lend itself to traditional methods for causal inference (e.g., randomized controlled trial with pre-defined outcome variables). Rather, learning from participants phenomenologically about their perceptions of their involvement may serve as an important starting point for investigating the role and collective impact of education networks.

3.1.2 Professional Identity

Professional identity can be understood as the conscious awareness of oneself as a worker, and it is often a major component of one's overall sense of identity (Skorikov & Vondracek, 2011). Taking an interdisciplinary approach to understanding identity formation, one that considers both institutionally defined interactions as well as personal identity, can help us to understand the process of professional identity formation as a lifelong journey (Côté, 2002). In the context of education networks, participation may serve as a transformative experience that launches an educator's career or takes it to new heights through professional development and

networking opportunities. Since professional identity, environmental context, and individual identity are often intertwined (Unruh et al., 2004), network involvement might also shape an educator's professional identity by validating their career choice and providing a supportive environment in which to meet and share knowledge with other educators.

Participation in networks might also help educators to create and grow meaningful, lifelong relationships with other educators. As Christiansen (1999) argues, "when we build our identities through occupations, we provide ourselves with the contexts necessary for creating meaningful lives, and life meaning helps us to be well" (p. 547). Christiansen (1999) proposes that personal identity shapes and is shaped by our relationships with others, that identities are closely tied to what we do, and that identities provide an important central figure in our life stories. Occupations, then, can enable people to develop and express their identities. In the context of education networks, members can be seen as a group of people with shared purposes, values, and interests, who collectively shape their identities through network participation over time.

3.1.3 Communities of Practice

To understand the various roles that educators take within networks, my approach is informed by research on communities of practice and the concept of legitimate peripheral participation. Communities of practice are groups of people who share a passion about a topic and who deepen their knowledge in this area by interacting on an ongoing basis (Baker & Beames, 2016). Legitimate peripheral participation is the process by which people in a particular field become experienced members and eventually experts within a community of practice (Lave

& Wenger, 1991; Ericsson & Charness, 1994). This process refers to how newcomers may be involved in a more peripheral way, that eventually leads to more central participation. In the context of education networks, legitimate peripheral participation might take the form of an educator mentoring another educator, and in doing so, encouraging that educator to one day become a mentor themselves. This cross-sectoral mentorship is particularly common in education networks because they promote collaboration among formal and informal educators. My analytic approach is also informed by literature on productive disciplinary engagement which refers to environments that allow learners to take on intellectual problems, address such problems and remain accountable to others, while providing resources to support these activities (Engle & Conant, 2002). Education networks might foster productive disciplinary engagement by hosting professional development sessions for educators to learn about culturally relevant pedagogy, for example, as well as by providing grants for educators to then implement new curriculum in their learning environments. Taken together, this literature base helps us to understand the role of education networks in shaping the professional identity of educators as well as how networks might circulate important ideas about equity in education. With this context in mind, I now describe a regional education network where over 1,000 individuals and 500 organizations participate as members in a collective effort to support the growth of relevant, engaging, and equitable learning practices.

3.2 Case Study of a Regional Education Network

To consider how educational networks might function in general and their potential as tools in equity initiatives, I present a localized case study of one network. In the early 2000s, a

group of leaders from a mid-size U.S. city's schools, museums, libraries, and community centers met to discuss the ways that technology was impacting education across the region. This meeting led to an ongoing conversation about the intersection of education and technology and the formation of a working group for the purpose of sharing innovative learning practices across sectors (Behr, 2015). In 2014, this working group evolved into a regional education network, and leaders adopted the following mission statement:

> [Education Network] is a collaborative effort to inspire and empower a generation of lifelong learners in [region] and beyond (Behr, 2015).

In this initial iteration of its mission statement, the words "collaborative," "inspire," and "empower" were used to describe an effort that was interdisciplinary, cross-sectoral, and geographically dispersed. The use of "lifelong learners" as a phrase acknowledged that learning happens in and out of school, over the course of a lifetime, as well as across generations. Importantly, this type of learning ecosystem framework presented a fundamental departure from a schooling-as-education approach because it acknowledged that learning and development occur throughout lifetimes and across both in- and out-of-school environments (Akiva, Delale-O'Connor, & Pittman, 2020).

Over the next few years, this education network grew from a few dozen members who met in the small office of a local foundation, to a stand-alone organization with hundreds of members, its own meeting space, and several full- and part-time employees (Behr, 2015). During this period of rapid growth and expansion, the network began responding to community calls for it to more deliberately focus on equity in education. Throughout this time, the network held a series of 20 roundtable conversations with community organizations, schools, and government leaders. Over 100 individuals participated in these conversations, and this led to the rewriting of its mission statement, which now reads:

> [Education network] ignites engaging, relevant, and equitable learning practices in support of young people navigating rapid social and technological change.

This later iteration of the mission statement includes the words “engaging,” “relevant,” and “equitable,” to describe the learning practices that it promotes, and it replaces “lifelong learners” with a focus on “young people.” The vision statement continues by stating that equitable learning is defined as affording support and opportunities to learners of greatest need. In this way, the network aims to equitably distribute innovative learning practices through a broad, city-based approach. Although schools can be an important context for learning, this network mission statement still acknowledges that a significant proportion of learning occurs in informal spaces such as museums, libraries, afterschool programs, community centers, online, and at home.

To carry out its mission of equitably distributing innovative learning practices, the network provides several engagement opportunities for educators. Working groups meet on a monthly or bi-monthly basis and are open to anyone to participate. Some of the current working groups include: a STEM working group, which was involved in a campaign to eliminate the SAT requirement for college admissions in place of an out-of-school time STEM credential; a rural working group, which engages rural educators in conversations about how to center anti-racism in their work; and a computer science working group, which promotes the sharing of culturally relevant curriculum for computer science teachers. Participation in a working group is voluntary, with educators deciding collectively what the goals of the working group should be, and each member volunteering to take on an aspect of operationalizing those goals. Working group attendance typically ranges from 25 to 100 network members.

"Meetups" and "lunch and learns," are often more informal than working groups, and provide educators with one-time opportunities to share resources or ideas on a particular topic or to listen to lecture style presentations from other educators about an aspect of their work. Examples of past meetups include: a researcher and educator meetup to discuss ongoing and potential research practice partnerships; a STEM learning through hip hop event to learn about a local company that uses hip hop to engage youth in technology education; and a maker learning meetup to share ideas about how to incorporate project-based learning in the classroom. In addition to working groups and informal meetups, the network also provides stipends for educators to travel to attend conferences, as well as small grants to support physical modifications in schools and community centers that support innovative and equitable learning. Additionally, as part of the process to rewrite its mission statement, network members identified five key demographics that would be the focus of the network: learners of color, learners in poverty, learners with disabilities, rural learners, and girls in STEM. In shifting its focus toward promoting equitable learning practices for these groups, the network made an intentional move to center social justice in its activities.

3.3 This Research

The present research is a case study (Patton, 2015) of one educational network, with geographic boundaries and particular aims as described in the previous section. I take a phenomenological approach (Williams, 2021), with the assumption that the perceptions of those involved in the network can provide a route to understanding the functions of the network. I address the following research questions: 1) What influence does participation in the network

have on educators? 2) Does network participation influence individuals differently, depending on their level of involvement? Ultimately, the answers to these questions will inform overall understanding of education networks and the potential of such a network to promote equitable education practices and structures.

3.4 Methods

3.4.1 Sample and Procedures

Since engagement with this regional education network varies for every individual involved, I recruited our samples at three main levels at which educators can participate in the network (see Table 3). Core participation describes those with network engagement of at least five years or those who have a formal leadership role in the network through a paid contract, such as working group leads. Mid-level participation describes those with network engagement of at least 3 years or consistent participation in a working group. Finally, peripheral participation describes those with limited network engagement of fewer than 3 years or limited participation in annual events.

Table 3 Network Participation Among the Interviewees

Participation Level	Description
Core (n=16)	Members who have a paid role in the network e.g. as a working group lead, or members who have at least 5 years of network engagement
Mid-Level (n=30)	Members who have been engaged consistently in the network for at least 3 years e.g. through the STEM working group
Peripheral (n=65)	Members who have been engaged for less than 3 years or who have sporadic involvement with the network e.g. through participation in annual events

In order to understand how members across various levels of participation experience this network, I conducted a series of individual interviews across the three participation types. All interviews were audio recorded. Interviews with core members (n=16) lasted approximately 45 minutes to 1 hour and were conducted in person. Interviewees were asked to describe the values and benefits of the network, how they understand equity in education, and how they define success for the network. The mid-level participation sample included school administrators, nonprofit directors, K-12 teachers, and informal educators. Interviews with mid-level participation members (n=30) lasted 45 to 60 minutes and asked interviewees to describe whether and how network participation has affected their professional identity, how they define equity in education, and what they see as the main benefits of network engagement.

Procedures for the peripheral participation group varied from the first two groups. These brief interviews (5 to 10 minutes each) were conducted by a team of ten university researchers and affiliates with a sample of members (n=65) who attended the annual network assembly. At this event - a large gathering for the network that attracts between 200 and 500 participants each year - we asked interviewees to describe what the network is and how engagement with it has affected them.

3.4.2 Analytic Coding Procedure

Interview analysis follows the In-Vivo coding method, which is a practice that assigns a code to an interview transcript using a key phrase or word from the interviewee's own words to honor their voice and perspective (Saldaña, 2016). To do this, I first transcribed and uploaded

interview audio files to Dedoose analytic software (Dedoose, 2021). Then, I used the verbatim words of participants to produce a series of codes that describe the various themes that emerged from their responses. For example, in response to the question, "How do you benefit from engaging with the network?", one participant responded, "I work in out of school time programs, right? So… I have been able to develop my knowledge and my skills and my network through [Network] programs." This response was coded as "Knowledge and skills development," and there were 18 instances of this code across the interviews. Using the axial coding method, I grouped these codes according to categories, and then grouped these categories into overarching concepts that inform this research.

3.4.3 Researcher Positionality

Before continuing to the research results, I will discuss how positionality might affect this study. I am a white woman who grew up in the region where this education network is located. Because I have spent a large part of my life in this region, I am familiar with many of the people and organizations that we interviewed for this study, and this familiarity means that I felt relatively comfortable approaching network members and asking them to participate in interviews. This comfort is tied to my identity as a white woman, as well as to my institutional connections with the university where I am working on a PhD. Particularly for individuals and communities who have been misrepresented and harmed by white researchers and white institutions, some interviewees may have felt a legitimate lack of trust in sharing information and thoughts with me. This could have resulted in some educators either declining to participate in an interview or agreeing to participate in an interview but not sharing critical views of the network.

Additionally, my analysis of the interviews is also influenced by my identity. For example, I may have been more likely to interpret interviewee responses as being less critical of the network and instead I could have been more prone to interpreting praise for how educators have benefitted from their network engagement. The implications of my positionality and of interviewee selection bias are therefore important to keep in mind when reviewing the results.

3.5 Results

3.5.1 Network Participation for Core Members

When asked, "What is the value and benefit of network engagement?" the single most common response among core participants was "building equity in education." Although some core members discussed equity work as needing to be inclusive and universal by using phrases like "all learners," others emphasized the need to be targeted in their outreach approach by engaging those who are marginalized by the current education system. For example, one core member stated:

> What would it look like if the network just owned like, we're about justice? We're about racial equity. We're about the future. We're about technology. We're about fun and celebration.

Similarly, when asked how they define equity and what it looks like in practice, most core members mentioned the equity focus areas, which the network created to identify the target demographic of rural learners, learners of color, learners in poverty, girls in STEM, and learners with disabilities. These focus areas are in theoretical alignment with the previous interviewee

response that the network ought to focus on justice, racial equity, and technology rather than addressing all learners regardless of socioeconomic status.

Another core member answered the question of what equity looks like in practice by describing the education system as a microcosm of the racist and inequitable distribution of resources throughout the city. This interviewee argued that the network is reckoning with this tension:

> I've been thinking a lot about what Black communities [in this region] already knew about the incredibly inequitable distribution of resources and the deep racism in our city. I see the network reckoning with that and shifting but that work needs to continue and go deeper. We've been at a critical point locally. The tension I'm talking about with equity, ed tech, and innovation, are playing out on a large scale in our education system broadly. It's a microcosm.

Identifying the education system as a microcosm within the broader regional and national context acknowledges that it is not schools or youth programs in and of themselves that are historically and systemically classist, racist, and ableist. Instead, this core member views schools and education systems as being one component of a larger nation building project that marginalizes students of color and those who live in poverty. In this interview response, equitable resource allocation is identified as the main solution for creating greater equity in education. Each of these core member responses defines power as located in people on-the-ground doing education work, specifically in marginalized communities, and describe policy creation as a distributed effort that starts from the bottom up, versus traditional top-down policy creation which can uphold the racial and economic privileges of those in power.

Other core members discussed the shift in the language that the network uses to describe its work, away from universal language such as "all" and "everyone" and toward targeted language that identifies racialized communities. One of the interviewees reported that this shift

was informed by John Powell's work on targeted universalism which explores how using universal language serves to uphold existing power imbalances and privilege existing social groups based on their race, gender, and class (Powell, Menendian, & Ake, 2019). This core member identified a main challenge for the network as the need for culturally white institutions such as museums, libraries, universities, and the network itself to work toward racial justice:

> The big switch in the language that we've used over time, especially in the last few years, has been no longer saying "this is an open and organic network" and switching from a language of ALL to these specific organizations, right? When you say ALL you're actually privileging certain people. This idea that any policy that has been enacted to serve all people and kids has always privileged those who already have privilege.

This core member also articulated that equity work does not happen in a vacuum and that the network must reckon with the issue that many communities do not trust the network because it was established by white-led philanthropic foundations and has been led by a predominantly white team. They explained one way to build this trust is through inclusivity:

> I think there are a lot of organizations that have every right not to trust [the network] and it will continue to be our work to change that narrative and change ourselves to be a more inclusive network. And part of that is leadership of color but it's not just leadership. It needs to be the entire network that needs to be more racially diverse, more gender diverse, more diverse in terms of sexual identity, more geographically diverse.

It is important to note that every core member interviewed described equity in education as being a key value of network engagement. While responses varied in how interviewees defined equity, there seemed to be a shared understanding that moving away from universal language can shift this culturally white network toward embodying racial justice in its work. In addition to core members identifying equity in education as the main benefit of network engagement, core members also discussed celebration of educators and professional networking as key benefits of network engagement, although these themes were discussed to a lesser extent.

3.5.2 Network Participation for Members with Mid-Levels of Participation

Table 4 provides a summary of most common responses to the question, "How has engagement with the network affected your professional identity?" among members with mid-levels of participation. The most often mentioned responses were about building a professional network of educators. Connecting with likeminded people both locally and nationally as well as using the online network member directory were mentioned as key to building a professional network. Particularly for informal educators, participation in the network helped to validate their career choice. Thinking more explicitly and critically about equity in education was also described as a direct result of participating in network events.

Table 4 Perceived Network Benefits for Educators with Mid-Level Participation

Themes	Mentions	Description	Example Quote
Building a Professional Network	15	Connecting with likeminded people, building a broader network both [regionally] and nationally, and using the online directory were all described as the main benefits of network engagement.	"I look at my participation with [the network] is that it has expanded my professional network. Even if I didn't directly or immediately connect with someone, or email with someone the next day, the next [network] event we would be like hey how's it going? You start to see faces, a lot of the same faces, so even if you're not getting to know someone by partnering with them, it is starting to grow that network of, hey I know you, I've seen you before."
Celebration and Validation of Profession	6	Particularly for educators who work in Out of School Time settings, the network has served to validate their career choice.	"My own family members didn't understand it, like that's not a real job. Just having that community that you're part of, where you can share your experiences. It validates your work. Even if it's just internal. It helps ground yourself, even if there are outside voices. No this is real,

			it's human services work even if it's not classified as such. I'm going to keep walking this path."
Centering Equity in Work	4	Some educators now think more explicitly and critically about equity in education as a result of participating in network events.	"I commend [the network] in thinking about equity critically, creating the equity pillars. It continues to push in terms of racial equity and segregation in [the region]. It keeps pushing me and people like me to think about this and implement it into the work. It's not just a one-time thing."

To consider alignment among network members with mid-level participation and core network members in terms of how they think about equity in education, I also asked mid-level participants to give their definitions of equity in education. The most common responses were "individualized education," "access," and "resource redistribution." Individualized education was generally understood as students getting what they need to succeed and thrive, with one participant noting:

> My personal belief is that equity is more than just having a seat at the table. It's about I have everything I need to not just succeed but to thrive. And my needs are different than anyone else's needs. So individualized, personalized learning are ways that we can get to equity in education.

Members describe individualized education as students having learning environments that are adaptable, flexible, and responsive. Access was described as "levelling the playing field" and providing "less fortunate" or "less privileged" communities with more opportunities. Resource redistribution was discussed in terms of redirecting support from over-resourced communities to those that are systemically discriminated against. Some of these responses - namely those that fall under the "access" category - seem to align with universal understandings of equality and opportunity which do not consider systemic discrimination. Other responses -

namely individualized learning and resource redistribution - seem to align with targeted understandings of equity.

For example, one member noted, “What types of organizations are getting supported? Who’s leading them? What do those people look like? Are they organizations that are led by POC, those most affected? That has a tremendous effect. We usually think about the students, but we skip over the effect of having someone that looks like you.” This targeted understanding of equity is a common theme among mid-level participants and shows that their network engagement is framed in terms of redirecting support from over-resourced communities in favor of those that are systemically discriminated against.

3.5.3 Members with Peripheral Participation

Throughout interviews with members who have peripheral participation, I set out to understand how these individuals understand what the network is and their perceptions of how their involvement has affected them. When members with peripheral network participation were asked to describe the network in their own words, many (n=28) described it as a network that is specific to educators for the purpose of improving learning both in and out of school. Other interviewees (n=15) described it as a network or gathering place for information sharing and inspiration but did not specify a purpose for this information sharing. Collaboration across sectors to improve education was identified as a key part of the network by some interviewees (n=12).

As is further summarized in Table 5, the main benefit of network engagement mentioned by most members with peripheral participation (n=36) was described as meeting people, learning about other organizations, and feeling part of a broader community. Knowledge sharing (n=18)

as well as grant funding (n=13) were also described as main benefits of network engagement. Importantly, neither equity in education nor professional identity development were mentioned as key benefits of network engagement by members with peripheral participation.

Table 5 Perceived Benefits for Members with Peripheral Participation

Theme	Number of Mentions	Description	Example Quote
Networking and celebrating with community	36	Meeting people, learning about other organizations, and feeling part of a broader community were mentioned as the main benefits of network engagement.	"I think one of the biggest things is really the network itself. And so being able to connect with other individuals who share similar passion, who are doing similar work, whose work complements and potentially enhances the work that we're doing, and even more so thinking about how I could also be a resource to others as well."
Knowledge and skills development	18	A key benefit of network engagement was described as learning about innovative teaching approaches and sharing ideas with educators from in and out of school settings.	"I work in out of school time programs, right? So even in that, as someone who works in that context and not as a K through 12 teacher, I have been able to develop my knowledge and my skills and my network through [network] programs."
Accessing grant funding	13	Seed awards and program launch grants as well as larger funding opportunities provided by the network.	"We were awarded a $50,000 grant… so just being able to grow with [the network] as they're growing has been a pleasure."

3.5.4 Looking Across All Three Interview Sources: Core, Mid-Level, and Peripheral

Examining response patterns across the participation groups allowed me to consider the degree to which perceived benefits of network involvement are similar and different depending on the audience. Validation of professional identity was not described as a key value of the network from the perspective of the core members, but it was described as the main benefit of

network engagement from the perspective of mid-level network members. I also saw that advancing equity in education was named as a key value of the network from the perspective of core members, but networking and community building were named as the key values of network engagement from the perspective of network members with both mid- and peripheral-levels of participation. The following table summarizes these key differences and similarities.

Table 6 Key Similarities and Differences Across Groups Regarding Perceived Benefits of Network Involvement: Number of Mentions

Participation Group	Advancing Equity in Education[1]	Building a Professional Network[2]	Celebration and Validation of Educators[3]
Members with Core Participation (n=16)	16 (100%)	12 (75%)	6 (38%)
Members with Mid-level Participation (n=30)	4 (13%)	15 (50%)	6 (20%)
Members with Peripheral Participation (n=65)	2 (3%)	15 (23%)	36 (55%)

[1] Advancing equity in education: Providing targeted support to key groups, centering work around racial justice, moving away from universal understandings of equality.
[2] Building a professional network: Connecting with likeminded people, building a broader network both in Pittsburgh and nationally.
[3] Networking and celebrating: Meeting people, learning about other organizations, and feeling part of a broader community

3.6 Discussion

This chapter yields several key findings. First, in the context of this case study education network, members identified perceived benefits that mostly fell into three main categories: advancing equity in education, building professional networks, and celebrating education and educators. Smaller numbers of interviewees also mentioned a few other topics: celebration and validation of the profession, gaining skills/knowledge, and gaining access to supports around

obtaining grant funding. Further, I found relatively strong indications that perceived benefits varied by levels of involvement in the network: peripheral members tended to note the celebration and gathering aspects of the network, members with mid-levels of participation tended to describe how their involvement helped in their career development, and core members emphasized the potential for the network to promote and advance equity in education and youth development.

Strong agreement emerged among core members that building equity in education is a key benefit of participating in the network. They described the evolution of the network, from generally focusing on technogy and education to making equity central. While there was some variation in how network members with mid-levels of participation understand equity in education, a few themes emerged around individualized education, access, and resource redistribution which were generally understood as students getting what they need to succeed and redirecting support away from over-resourced communities. The core members widely agreed that a step in promoting equity in education involves moving away from universal language in favor of targeted language for educators who serve learners of color, learners in poverty, girls in STEM, learners with disabilities, and rural learners.

From the perspective of network members with mid-levels of participation, the main benefit of network engagement was described as building a professional network. Particularly for some informal educators with mid-levels of network engagement, participation in the network has also helped to validate their career choice. Importantly, I also found that some network members with mid-levels of network engagement attribute their ability to think more explicitly and critically about equity in education through their participation in network events.

Considering results across the three types of members, I found that educators who are first entering the network, or those with peripheral participation, are primarily interested in celebration and networking. This makes sense as educators often enter the network by attending a celebratory gathering. However, I also found that for those who remain engaged over a prolonged period of time, network engagement is consistently reported as contributing to their professional identity development. Because core members expressed widespread agreement that the main value and benefit of network engagement is building equity in education, this suggests that core participation is where transformative equity work can happen for individuals. Importantly, for education networks that aim to promote ideas like access and equity, this finding also suggests that celebration and networking can serve as an entry point into deeper, more transformative engagement.

As my findings suggest, this regional education network provides validation and celebration of the career choice of educators, which might help educators to feel less isolated and encourage them to "keep walking this path." Network engagement has also helped to circulate important ideas about centering equity in education, potentially through issue specific working groups. However, because this was the third most mentioned benefit of network engagement among members with mid-levels of participation, this suggests the opportunity for future research to uncover the specific mechanisms by which ideas about equitable learning practices are circulated. Finally, among members with peripheral participation, grant funding was mentioned as a main benefit of network engagement which suggests that the network can provide resource redistribution through targeted support of educators that serve girls in STEM, learners of color, learners in poverty, learners with disabilities, and rural learners.

In addition to the practical implications, this study also has implications for future research. As existing research has shown, education networks take on the role of convening, networking, coordinating and facilitating in order to intentionally shape learning systems by promoting new ideas and building structures for change (McAdam et al, 1996). The present study adds the notion that when education networks are explicit in their naming of equity as a key value, then it becomes possible for educators to engage in transformative equity work even if their initial participation is centered on networking and celebration. By creating strategies that attract educators to the network and then providing the necessary support to move these educators from the periphery to the center, networks have the potential to build more equitable education systems.

For example, an education network could start hosting an annual assembly that brings together hundreds of organizations to attract educators to the network. Those educators - who start as peripheral participants - might then experience the validation and celebration that joining an education network can provide, thus developing their professional identity and contributing to their overall identity (Skorikov & Vondracek, 2011). Throughout the process of joining this larger structure for change, participants would have the opportunity to join working groups, participate in professional development, and apply for grants to support their work, thereby moving toward the mid- and core- levels of network participation. Through consistent working group participation, building relationships with other educators and network members, and professional development, these once peripheral participants might find themselves becoming experts within this community of practice, thereby starting the process all over again by then turning to provide support and expertise to new and incoming network members. What might look like networking, fun, and celebration on the surface could actually serve as an important

mechanism by which educators are made to feel validated, supported, and welcomed into a transformative community of practice. In other words, by coming together with other educators to share their passion and learn from one another, education networks can strengthen the relationships that educators have with one another and create new communication channels that serve to circulate important ideas about how to address educational inequities (Baker & Beames, 2016).

When considering legitimate peripheral participation as the process by which people in a particular field become experienced members and eventually experts, future studies can help us understand the specific mechanisms by which educators move throughout the various levels of network participation (Lave & Wenger, 1991; Ericsson & Charness, 1994). For example, members who have moved from peripheral to core levels of participation might provide further insight into why educators move throughout networks in the ways that they do. The explanation of this movement might also help explain how educators come closer to learning about ways to center equity in their work. The results of such research could make meaningful contributions toward understanding the process by which educators engage in transformative learning practices and thus create systemic change.

Finally, with the ongoing pandemic of COVID-19 exacerbating existing educational inequities, now is a particularly important time to understand how professional networks might support educators and center issues of equity. At the same time, the Black Lives Matter movement has brought attention to the urgency of addressing equity and anti-racism in education and educators across informal and formal learning contexts are becoming increasingly concerned with doing so. My findings suggest that education networks can be a context for members - particularly those with substantial involvement, to learn about and advance equity through their

network participation. While addressing equity in education is a complex problem, this case study highlights the salient need to build professional networks, a need which is largely unmet across education. In this sense, professional networks meet multiple, complex needs across a broad spectrum of organizations and professional learning contexts. For this reason, there is significant potential for professional networks to equitably distribute innovative learning practices through a broad, city-based network, while validating educators and supporting learners in the process.

3.7 Study Limitations

It is important to note several limitations of this study. First, because network membership is free and voluntary, it is unclear how selection bias might affect which educators come to participate as members of education networks. In other words, who does not participate and why? This research study does not answer the important question: What does the professional identity of educators look like when they are not engaged in education networks? Second, due to the emergent nature of education networks and learning ecosystems, it is difficult to make causal statements about how network engagement affects individual members and organizations. There is also a gap in the findings in terms of understanding the specific activities and conversations that educators engage in, which are transformative for their practice. Finally, it remains to be seen whether most educators do in fact move from the periphery to the center of education networks, and if so, how this movement occurs. The current study has not addressed these important questions, but future studies of education networks could offer helpful answers to these questions.

3.8 Conclusion

As I have discussed, this study finds that there is a cohesive narrative about the values and benefits of network engagement among core members, namely advancing equity in education. Thematic analysis of interview transcripts suggests that equity in education is conceptualized by members as individualized learning, access, and resource redistribution. Analysis also suggests that the main impact of network engagement for members is development of their professional identity, validation and celebration of their career choice as educators, and learning how to center equity in their professions. The implications of this research may help education networks better understand how to circulate important ideas about equitable learning practices as well as how to strengthen and validate the professional identities of educators.

4.0 Interrogating the Transformational Potential of a Feminist Makerspace

4.1 Introduction: Why Feminist Makerspaces?

From elected officials to school administrators, the maker movement has captured the attention and hopes of many across the globe as having the potential to increase access to design and fabrication tools and ultimately to diversify the pipeline for careers in Science, Technology, Engineering, and Math (STEM). In the United States, President Obama launched the Nation of Makers initiative to provide learners with more access to new technologies such as 3D printers, laser cutters, and desktop machining tools. In Europe, the Joint Research Center of the European Commission launched an international makers-in-residence program to promote collaboration among scientists and community members. However, it is unclear what this global makerspace movement has done to address the problem of the 'leaky pipeline' or 'gender filter' (Blickenstaff, 2005) for women in STEM.

In this chapter, I focus on how feminist makerspaces can move from being concerned with access and inclusion in technological fields toward transformation of these spaces. I understand transformation as both personal and institutional. Transformational change at the individual level might look like white women practicing humility when partnering with racial justice organizations. Transformational change at the institutional level might look like redistributing resources toward Black led racial justice organizations.

Throughout this chapter, I take up an autoethnographic approach, examining my experiences of co-founding the feminist makerspace Prototype PGH to reflect on how the space evolved over time to take direction from community members and align itself with broader social

justice movements. In doing so, I argue that feminist makerspaces are a model for more equitable STEM learning environments, particularly in their efforts to build coalitions, seek autonomy from corporate influence, and center racial justice in their work. To build toward this argument, I offer background on the evolution of makerspaces, highlighting concerns that these spaces have invisibilized the contributions of women to maker economies. I then discuss related work that explores feminist responses to the makerspace movement. Finally, I pair this retrospective autoethnography with 11 semi-structured interviews to center the experiences and perspectives of feminist makerspace members and community partners.

4.1.1 The Mainstream Maker Movement and Feminist Counter-Spaces

According to media studies scholar Maxigas (2012), hackerspaces emerged in Europe in the 1990s as a means of providing free access to the Internet and digital equipment, as well as expressing an anarchist tech ethos by offering space to take apart, hack, and recycle electronic parts. In the decade and a half that followed, the founding of *Make Magazine* and Maker Faire played a central role in introducing makerspaces – which evolved from hackerspaces to include equipment for making – to wider audiences. Organizers of Maker Faires and affiliated makerspaces promoted this movement to share tools, knowledge, and community in a member-based space (Rosner & Fox, 2016). The wave of interest in making led by *Make Magazine* and marked by slogans such as “maker to manufacturer” and “nation of makers” sought to democratize access to manufacturing tools, sparking an international move to franchise community makerspaces.

Despite this enthusiasm and investment, such spaces often left out forms of craft practice present elsewhere such as ceramics, costume-engineering, and weaving, while largely attracting white, male members. Through this process of mainstreaming, craft practice was "overlooked, underrecognized, and often undercompensated and exploited" (Rentschler, 2019). In placing emphasis on circuit boards and soldering irons over sewing or textiles, the Maker Movement overlooked rich, global histories of artisan and maker economies. According to the international non-profit Nest, "upwards of 300 million people [predominantly women] around the world work from home, engaged in primarily craft-based handwork." (Bergen, 2021). However, an early analysis of *Make Magazine* cover images found that of the 40 people featured, 85% were men and boys and none were people of color (Quattrocchi, 2013). This portrayal of makers as white men from the Global North serves to erase the contributions of women from the Global South who have been involved in making and hacking activities for centuries. Importantly, this erasure of racialized women from the maker movement echoes the findings in my education network study that using language such as "all" and "everyone" serves to uphold existing power imbalances and privilege rather than promote inclusivity (Powell, Menendian, & Ake, 2019).

While the popularity of makerspaces has grown over the last two decades, so too have feminist critiques of the unspoken but pervasive white, heteronormative, patriarchal values that often serve as the foundation for these spaces. The Geek Feminism wiki, started in 2008, created a foundation for what would become the feminist hackerspace movement. On this forum and the associated email listserv and blog, individuals shared their experiences of sexism and discrimination in geek culture (Toupin, 2014). While these topics had not previously been widely discussed at tech and open-source conferences, Toupin outlines how Geek Feminism wiki participants began to see that their individual experiences were much more commonplace than

they had initially thought, and that their legitimate concerns about sexism in technology were shared by many others.

Emerging from these online discussions, from 2008 to 2014, several hackerspaces formed in Europe and North America specifically focused on serving women and people of color (Toupin, 2014). These included Mz Baltazar's Laboratory in Vienna, Liberating Ourselves Locally in Berkeley, Mothership Hackermoms in Berkeley, Seattle Attic in Seattle, Flux in Portland, Double Union in San Francisco, and Hacker Gals in Michigan.[2] Scholars argue that feminist makerspaces and hackerspaces grew as an alternative to the dominant makerspace movement by starting with the notion that technology design and use are value-laden and politically invested (Foster, 2019). Instead, feminist hackerspaces are organized around a politics of care, a strategy rooted in interdependence and a commitment to prefiguring the world members need (Ibid, 2019). These spaces have been shown to foster feelings of well-being and empowerment among their members and create space to work together on small-scale design projects that challenge dominant understandings of technology and collaboration (Capel et al., 2021; Fox et al., 2015). Weaving and identity workshops become sites of resistance to patriarchal notions of what constitutes hacking and making. Doing so shifts the conversation from access and inclusion to recognition and visibility within wider tech cultures (Fox et al., 2015). Other researchers have studied how hacking and taking apart devices serves as a metaphor for deconstructing and reimagining gender roles (Savic and Wuschitz, 2018). These researchers argue that disassembling an electronic device "not only breaks the hardware, but also

[2] At the time of writing, Seattle Attic, Flux, and Hacker Gals are no longer in operation. Based on interviews with the founders of these spaces, financial troubles and failure to create a broad-scale approach to addressing systemic inequities, were the most commonly cited reasons for their closure (Removed for anonymous review).

breaks with feminine gender scripts, the norm on how to perform femininity (not be 'aggressive' and not avidly 'destroy')" (Ibid, p. 10).

The present study expands on this line of scholarship by focusing on what feminist makerpaces are capable of achieving in their pursuit of transforming STEM learning environments. While many of these spaces developed largely out of concerns about sexism and gender disparities in mainstream makerspaces and tech companies, it raises the important question: what about racial equity and justice? Dunbar-Hester (2020) argues that decentering dominant groups requires more than simply adding members of minoritized groups and that, "While attention to diversity is necessary, it is far from sufficient for an anti-racist social justice agenda" (p. 21). For this reason, I explore how feminist makerspace participants grapple with issues of racial justice and the degree to which they see racial justice playing out in the activities of the space.

4.1.2 Informal STEM Learning's Turn to Makerspaces

Women are underrepresented in STEM fields' formal educational contexts such as the university, and as a result, are also underrepresented in STEM careers. Often referring to it as 'the leaky pipeline,' researchers of this phenomenon describe how students initially express interest in STEM fields while in secondary school, but then lose interest in university (Blickenstaff, 2005). Others may graduate with a STEM degree but then choose another field as a career. In a meta-analysis of scholarship examining why women leave STEM fields, Blickenstaff surfaces a study by Elaine Seymour (1995) which found that the pedagogy of science teachers is cited by over 90% of students as a reason why they chose to switch out of science. When students view teachers as being unapproachable, distant, and not caring or

supportive of student needs, women are less likely to remain enrolled in science majors. Other work found that girls generally receive less attention from teachers regardless of the subject or age of student (Wilkinson & Marrett, 1985; Sadker & Sadker, 1994). While these problems of instruction are not limited to science, Blickenstaff found that it is more pronounced in science and math classes, where teachers are more likely to be men. As such, the problem of this 'gender filter' (Blickenstaff, 2005) in STEM might be addressed through greater representation of female teachers and more access to informal STEM learning environments which have less barriers to entry.

For this reason, libraries, museums, and community organizations are all taking part in the informal STEM learning movement and creating their own makerspaces where exploration and creativity are welcomed as learning practices. In a study to inform policymaking for education and training in Europe, researchers found three unique aspects of makerspaces: 1) making activities combine disciplines that are otherwise taught separately, 2) participants explore "real world" problems in makerspaces, and 3) informal social interaction in makerspaces leads to more peer learning and mentoring than in formal contexts (Vuorikari et al., 2019). A U.S.-based study of three community-based makerspaces similarly found that the use of tools, sharing of knowledge through collaboration, and the making of objects were found in all three spaces (Brown & Antink-Meyer, 2017). These opportunities for increased collaboration, mentorship, and peer learning might also serve to increase gender and racial equity.

However, human-computer interaction researchers found that Danish library makerspaces provide limited scaffolds for skills progression and that the focus is on learners' skills for using the available tools rather than defining meaningful projects (Einarsson & Hertzum, 2019). Similarly, public makerspaces in libraries provide free access to tools and equipment to

community members but it is unclear which learners benefit and which learners are excluded from the teaching practices in these spaces (Willett, 2016). For example, a Brazil-based study of makerspaces found that simply being present in makerspaces is not enough to promote meaningful learning and a sense of belonging in STEM for female students (Russo et al., 2021). Similarly, in the U.S. based National Study of Makerspaces (2018), Kim et al. found that the spaces included in their study exhibited gender imbalance within leadership positions: 76% of the leaders were men and 24% were women. Importantly, the authors note:

> Gender parity was documented in K-8 makerspace participation, where girls made up a nearly equal proportion of student participants. The spaces included in our study, however, exhibited a sharp decline in makerspace participation among girls between the K-8 grades and high school, where female representation dropped to 25% (Kim, 2018).

But what causes this drop in makerspace engagement among girls? Work and technology researcher Greene suggests that while libraries and schools frequently win funding to pursue technological solutions (such as makerspaces) to complex social issues (such as systemic racism and sexism) they often marginalize and alienate women and communities of color (2021). STEM learning researcher Melo has investigated this question further by researching how gender identity potentially impacts the creation processes and behaviors of learners in makerspaces. Her research has found that 1) men-identified users are more mobile in makerspaces than women-identified users, 2) conventional makerspaces are readily coded as being either associated with men or women, and 3) participants point to gender identity as a factor informing their decision making during their collaborative making experience (Melo, 2020). These findings suggest that the gender and racial identity of participants is a crucial factor to consider in developing equity-focused makerspaces.

Throughout this discussion of related work, I have found that the wave of interest in making has sought to democratize access to manufacturing tools and sparked an international move to develop community makerspaces. Although the mainstream maker movement has often been touted by policy makers and school administrators as increasing access and equity in STEM, it has often replicated the very power dynamics it aims to address. As a response to this movement, feminist makerspaces have worked to center womens' lived experiences in workshop pedagogy, deconstruct traditional gender roles and expectations through making, and resist dominant notions of what constitutes knowledge. In the next section, I examine the work of one U.S. based feminist makerspace to build coalitions, center racial justice in its activities, and seek autonomy from corporate influence.

4.1.3 Prototype PGH

Prototype PGH is a non-profit organization co-founded in 2017 by two cis-gender white women (including myself), with a mission to build gender and racial equity in technology and entrepreneurship. By providing free education programs through its makerspace, Prototype aims to take an explicitly feminist approach to workshop instruction in a way that centers the experiences of women and marginalized communities including those who are racially minoritized, have low-incomes, and those who identify as LGBTQ+. Founding members of Prototype believed in the potential of feminist makerspaces and hackerspaces to create more equity in education by engaging adults of all genders in free workshops that prioritize instructors from marginalized communities. As such, Prototype was imagined by its founders as an organization that could challenge existing sexist and racist structures by creating a communal space for adults to engage in dialogic and liberatory practices (Freire, 1970).

4.2 Methods

From March 2020 to June 2020, I conducted 11 semi-structured interviews with members of Prototype, as well as community members who lead racial justice organizations with whom Prototype has partnered. I conducted interviews virtually and each lasted between 60 and 90 minutes. Most interviewees are currently based in the same city as Prototype, or they lived and worked in this city during the creation and growth of Prototype.

4.2.1 Autoethnography

I employ retrospective autoethnography, using my experiences of co-founding Prototype to reflect on how feminist makerspaces can be a model for more equitable STEM learning environments. As Bell et al. (2019) argue, "autoethnography must of necessity be a generative and enabling frame for mining the possibilities borne of our defiant dreams" (p. 9). As such, one's own experience becomes an object of study and a source of knowledge. It is important to note that I was prompted to do this retrospective autoethnographic work because of a conversation in 2019 with a colleague who is a non-binary person of color. During a conversation about what constitutes liberatory learning environments, I claimed that Prototype aimed to build gender and racial equity through feminist workshops that center the experiences of women. My colleague argued that this would be difficult to achieve because, "Feminism is a white woman's movement." This conversation led me to reflect on how racial justice can be a core commitment and value in feminist makerspaces and how such spaces can work to eliminate racial disparities in our communities.

4.2.2 Interviews with Makerspace Members and Community Partners

Four of the interviews are with founding members of Prototype, another four interviews are with current members of Prototype, and three of the interviews are with founders of racial justice organizations with whom Prototype has partnered on city-wide initiatives. In terms of the gender and racial demographics of the interviewees, four of the interviewees are cisgender women of color, one of the interviewees is a non-binary person of color, one of the interviewees is a cisgender man of color, one of the interviewees is a white transwoman, and four of the interviewees are cisgender white women. Interview questions centered around interviewees' motivations and ideals for joining a feminist makerspace, how they have seen racial justice reflected in the activities of the space, and in what ways the space has change over time.

I analyzed this data using the In-Vivo coding method, which is a practice that assigns a code to an interview transcript using a key phrase or word from the interviewee's own words to honor their voice and perspective (Saldaña, 2016). To do this, I used interview transcriptions to identify the verbatim words of participants and then I produced a series of codes that describes the various themes that emerged from their responses. Using the axial coding method, I then grouped these codes into overarching concepts that inform this research. Three central themes that emerge from across these empirical engagements include being accountable to communities through coalition building, understanding racial justice work as an ongoing commitment, and troubling corporate connections to community-based projects.

4.3 Findings

4.3.1 Economic Justice and Coalition Building

From the beginning, conversations about starting Prototype centered on the values of cooperative economics and creating a physical space to build community and share knowledge. Many of these values stemmed from conversations among the founding members who wanted to see a makerspace that was financially accessible and that did not contribute to gentrification. This was particularly important because the city where Prototype is located has been rated one of the worst in the United States for Black residents with regard to quality of life, education outcomes, home ownership, and income levels, particularly compared to white residents.[3] For these reasons, the founders of Prototype wanted its future building and neighborhood to be: 1) centrally located and close to public transportation, 2) close to other businesses and entities that share similar values, and 3) in a working- and middle-class neighborhood where residents were unlikely to be displaced. To define this vision ahead of time, Prototype founders held a series of conversations with prospective members over the course of a year while looking for affordable warehouse spaces around the city.

The conversations started when Prototype founders became involved with a group of artists and activists who were interested in buying an empty building for shared workspace. This building had sat empty for decades after once serving as a family-owned metal working facility and glass door manufacturer. With the two dozen tenants, each organization's rents would be far below market rate. The other tenants in the building included a hip hop recording studio, textiles

[3] Citation withheld for peer review

and sewing workspace, tattoo shop, performance theater, and woodworking studio. According to one Prototype member, who is a transgender white woman, considering our proximity to these other organizations was important in her decision to join:

> I felt like I would feel safe and included at Prototype. It seemed like it would be core to the mission. To be gender equitable, in whatever form of gender that is. But also it seems like all of the businesses and organizations in the building are liberal, open minded, very inclusive, supportive of whatever we're trying to do so I figured if Prototype was in that space, it would also be inclusive.

In this way, Prototype was able to align itself with other social justice organizations and build a culture of mutual support throughout the collectively run warehouse. Yet, when asked later as a part of this study about what members valued about Prototype, it was not the physical space, the workshops, or the equipment. Instead, it was the mission of the organization and the community they found there. For example, one Prototype member, who is a cisgender white woman, viewed Prototype's partnerships with other social justice organizations to provide free workshops as a form of resource redistribution:

> One of the things that I really appreciate that's happening at Prototype is that those workshops [with partner organizations] and that space is free to people who are residents of [the local neighborhood]. That I would say is one example of a way that resources can be shifted a little bit. You know, by someone like me paying membership for Prototype, those resources can be kind of redistributed to other people who don't have the same resources that I do.

Similarly, another member of Prototype, who is a cisgender woman of color, noted that expanding access to community members in the local neighborhood would allow for more targeted engagement with low-income communities:

> If I could just magically wave a wand, it would be to have a larger space where we are able to attract members of the community who may not know about us. Even trying to fill up our workshops, what if we had a huge space with workshops that were filled up. Or a retail space where people could come and sell their own work.

This member highlights the need for informal STEM learning environments to be malleable by members of the wider community such that they can be used according to community needs. This might include selling member-made goods to support the entrepreneurial activities of the community or organizing and promoting workshops that are created, led, and instructed by the community members the makerspace aims to serve. Additionally, providing free access to low-income community members and building coalitions with social justice organizations are also key to centering racial justice in the work of community-based makerspaces. As one Prototype member, who is a cisgender Black man, noted:

> You can have the best programs and resources, but if people don't have a clue, then it doesn't matter. You need to coordinate with people who want to do the same type of work. Get more people to get engaged. Any sort of opportunity where you can create pathways to growth is a good idea. But that's not the sole mission. How do you continue to expand access outside of just job training. How do we help people become their best advocates?

As part of Prototype's continual reflection and growth, this member notes that it must work in partnership with other organizations doing economic justice work. Toward this end, Prototype has partnered with local business incubators, universities, and the Mayor's Office to provide a comprehensive year-long incubator that pays emerging business owners from marginalized backgrounds to participate. Marketing this incubator as a program for new and emerging business owners who have little to no experience allows Prototype to reach an otherwise marginalized audience that might not be inclined to be in a business incubator. Furthermore, partnering with the Mayor's Office to promote the program, as well as connecting incubator participants to more established university incubators creates a city-wide network that community members can leverage.

In summary, I found that Prototype initially offered free, skill-based workshops that its founders thought would be useful to the community. However, what founders and members

learned is that coalition building and being flexible in response to community needs is a necessary strategy for engaging diverse constituents. In addition to offering free workshops to low-income community members, informal STEM learning environments must also join regional efforts to build economic justice for marginalized communities.

4.3.2 Centering Racial Justice

In the context of community-based makerspaces, having a racially diverse Board of Directors and membership can be one step toward building gender and racial equity in STEM learning environments. As one Prototype's founding members, who is a cisgender white woman, noted:

> When we think about spaces designed for critical discourse, who gets to be participatory? That's the groundwork from which great ideas arise. But if you only let people who fit the criteria for who gets to be a great man, you cut the discourse short around what the future looks like.

As such, informal STEM learning environments must critically examine who is participating in their discussions and from whom the organization is taking direction. As part of its earlier work, Prototype secured corporate funding to support Black women leaders of racial justice organizations in workshop development. Some of these workshops were open only to Black women and focused on healing from the traumatic effects of generational poverty and systemic racism and sexism. Other workshops focused on learning entrepreneurship and manufacturing skills such as building a business, laser cutting, 3D printing, and 3D modelling. According to one community partner, who is a cisgender Black woman, and with whom Prototype partnered on this city-wide initiative:

> It's not about "was racial justice achieved?" […] Social justice is a practice, and a hypothesis that if we do these things, it will result in equity...It's about the long term project of creating economic equity for Black women in the city. It requires different trials, strategies, but because we live in a capitalist society, and everyone has a different definition of economic well-being, we haven't had a conclusive consensus on what that looks like.

As this community partner notes, creating economic equity for Black women and viewing racial justice is a continual process. Particularly in the context of the U.S. where systemic racism is pervasive in institutionalized learning environments and where Black communities' earnings lag those of white communities, centering the economic needs of Black women is critical in creating a more racially just society. If makerspaces are not actively uplifting the knowledge and experiences of Black women, they are at risk of replicating the white, male, middle-class status quo that is prevalent throughout too many STEM learning environments.

As such, reparations and shifting power were also identified as key themes in my interviews with Prototype members about how racial justice can be more central to the work. As a Prototype member, who is a cisgender white woman, noted:

> Makerspaces or any organizations can say, we're welcoming and open to anyone. But if the actual space itself is just full of white people, it's practically, on the ground, not welcoming. Racial justice and equity means that there shouldn't be any barriers for people - anybody - regardless of their race or ethnicity. I also think that reparations might be part of that.

In the context of makerspaces, reparations might look like providing resources to support workshops that are only open to participants from marginalized communities, where instruction is also led by instructors from these communities, and where community knowledge is valued and uplifted. Further, reparations might involve offering free or reduced cost for participation in

these workshops if community members identify as being part of a group that is systemically discriminated against in traditional educational and STEM learning cultures.

From the perspective of a founding Board member of Prototype, who is a cisgender white woman, challenging racism in friends as family is also critical to racial justice work:

> How do we actually see a shift in the way the world works? It's people who have been given power and privilege, giving up some of that power, but it's also about deep meaningful connections, friends, family, love that happens across racial and gender lines, that's when people really start to shift on those unconscious biases and start to see people differently.

For white makerspace participants, racial justice work might look like engaging in conversations with family members who have racist or sexist opinions and beliefs. As this member suggests, doing so can contribute to efforts of dismantling white supremacy culture within our own communities and at home. As the nonprofit organization National Education Association Center for Social Justice notes, white supremacy culture is a form of racism centered on the belief that white people are superior to people of color and that white people should politically, socially, and economically dominate communities of color (2020). Developing a culture of appreciation, challenging tendencies of perfectionism, accepting that there are many ways to arrive at the same goal, and including people who are affected by decisions in decision making, are all antidotes to white supremacy culture (Okun, 1999). Furthermore, racial justice scholars have noted that it is important to differentiate when organizational leadership should take responsibility for racial justice education projects versus when to take direction (Wilmot, 2005). Particularly, when engaging in racial justice work with women of color, Wilmot proposes that the role of white women ought to come from a place of solidarity against white oppression. In other words, as an organization founded by two cisgender white women, Prototype might contribute to the ongoing work of racial justice by taking responsibility for educating other white

people about racial injustice and taking direction from communities of color in supporting their work. By partnering with Black-led racial justice organizations, Prototype can work with community organizers to create economic equity for Black women in its city.

To emphasize this point, another community partner who leads an organization that primarily serves Black women and mothers, spoke about the importance of coalition building, growing a membership base gradually over time, and knowing when to call on others for their expertise. With regard to the nonprofit organization she founded to serve her community, this partner of Prototype, who is a cisgender Black woman, noted:

> We didn't have 50 people beating down our door when we first opened. The longer you stay at it, you maintain your consistency, people continue to walk through the door and bring people with them. You keep doing your thing. When you stop doing it, or start doing things you don't know anything about, you start doing harm. If I don't know the answer, I'm cold calling somebody.

This community partner notes that non-profit organizations must know their constituents well, provide consistent programs and services, and ask for help when something is outside of their wheelhouse. By taking a more collaborative role and partnering with organizations across the city, participants of feminist makerspaces can hold themselves accountable to larger social movements for gender and racial equity, ensuring that they are not just part of an organization but part of a broader movement as well.

In summary, I found that Prototype initially focused on having a racially diverse Board of Directors and membership as one way to work toward racial justice. However, what founders and members learned is that marshaling resources to support programs that serve women of color and Black women in particular would help meet existing needs in the region. Furthermore, Prototype members also communicated that creating a separate space for unlearning white supremacy culture among white peers is an essential part of doing racial justice work.

4.3.3 Troubling Corporate Connections

Interviews with Prototype members and community partners provide us with a starting point for thinking about how feminist makerspaces can become less reliant on institutional and corporate philanthropy. This reliance is troublesome because philanthropy often provides individualized and competitive short-term funding in the name of remedying complex, long-term, and systemic problems that might be better solved by broad social movements (Smith, 2017). One community partner, who is a Black cisgender woman and with whom Prototype partnered on the city-wide initiative to engage Black women in technology and entrepreneurship workshops:

> We need to think about the white supremacist foundations of western libraries...the legacies of people who exploited workers and then tried to make themselves feel better through philanthropy. Reparations and justice are in the lived experience of how we come to terms with this...What does a space for liberation look like? What does it mean for people on this planet to have access to the possibilities that allow them to thrive? And dismantle the behaviors, ideas, structures, that have made us violent toward each other.

As this community partner emphasizes, western philanthropy–whether it is related to funding libraries or makerspaces–is tied up in capitalist and colonial origins. For example, although capitalist philanthropists like Andrew Carnegie invested their wealth into the creation of library buildings, many U.S. libraries remained racially segregated well into the 1960s. Policymakers during this time barred Black citizens from having access to shared educational resources because doing so could allow them to learn about their shared history and collectively organize for civil rights (Knott, 2015). This is particularly relevant in Pittsburgh because the wealthiest philanthropists earned their profits from widespread industrialism, yet at the same

time, these philanthropists were often engaged in union-busting activities of industrial workers. For instance, in 1914 the Rockefeller Foundation "identified research and information to quiet social and political unrest as a foundation priority…the rationale behind this strategy was that while individual workers deserved social relief, organized workers in the form of unions were a threat to society" (Smith, 2017, p. 4). Similarly, it is important that community-led makerspaces not succumb to what Dylan Rodriguez defines as the "Nonprofit Industrial Complex" in which the state uses nonprofits to control and monitor social justice movements. For example, INCITE! is a national organization dedicated to ending violence against women of color that issued a statement in support of the Palestinian right to self-determination. In response, one of its major funders, the Ford Foundation, pulled their support of the organization (Smite, 2017). Becoming less reliant on corporate and philanthropic funding, therefore, might allow informal STEM learning environments to be accountable to larger social movements and have their agendas determined by the constituents they serve rather than the corporations and foundations that fund them.

In addition to becoming autonomous from philanthropic institutions, another Prototype member argued that feminist makerspaces should use free and open-source software to reduce reliance on corporations. As an alternative to licensed software, open-source platforms often have many independent programmers working to test and improve the software. As such, open-source software is not dependent on a particular inventor or company, so even if a company fails, the software can continue to be used and modified. According to this member, who is a non-binary person of color:

> It's important to use free and open-source software. I'm uncomfortable using Zoom and Slack and those sorts of technologies. But it's hard to go against that current. Sometimes it's too much emotional labor for me to push for it. I don't always because it takes a lot

> out of me. I would not be comfortable using anything else besides Signal because I see privacy as a community problem, not an individual problem.

Being the sole voice in an organization who is advocating for free and open-source software can be a significant emotional drain. As such, this member noted that it should be a collective effort on behalf of the entire organization to use such technologies. After speaking with this member as part of this autoethnographic research process, Prototype has started to switch over from corporate meeting platforms and communication channels to free and open-source channels. By refusing to engage with corporations that profit from the private information that users share, feminist makerspaces can take one step further toward financial and institutional autonomy. This is important because funding and technical infrastructure serve as the foundation upon which the learning environment is built. For example, if the values of those who produce this framework are incongruent with those of the community, then those interests can usurp power away from the makerspace and its members. Funders can demand that money be used in ways that do not align with community priorities, which can take precious time and energy away from the community projects and reduce the autonomy of the people who make up the space. Using proprietary software both removes the ability to own the infrastructure and opens up the possibility of subjecting community members to corporate and state surveillance. Whereas using free and open source software opens up the possibility to remake and fully own the very platforms and infrastructure that the members use and produce.

In summary, I found that Prototype initially used corporate investments and proprietary software to support its activities and partnerships. However, what Prototype founders and members learned is that social justice work must be a community led, regional effort that extends across organizations. Doing so might help to ensure that the equity-focused STEM learning

environments do not rely on corporate or foundation funding, which can change at any moment depending on institutional priorities and political climate.

4.4 Discussion

Although the maker movement has captured the attention and hopes of many people across the globe who see potential in its efforts to democratize access to innovative tools and equipment, it has done little to address the problem of the 'leaky pipeline' or 'gender filter' for women in STEM. Informal STEM learning environments and mainstream makerspaces have reinforced harmful stereotypes, portraying white men as makers, which serves to invisibilize the critical contributions of women and people of color to creative economies. However, feminist makerspaces demonstrate potential to challenge these dominant narratives and support women and communities of color in their pursuit of developing technical skill and building endeavors for both livelihood and leisure. I examine feminist makerspaces as a model for more equitable STEM learning environments, particularly in their efforts to build coalitions, seek autonomy from corporate influence, and center racial justice in their work. I now focus on how responses undertaken by Prototype members toward creating transformative and liberatory spaces could be applied to other educational contexts.

4.4.1 Mutual Aid and Coalitional Survival

Throughout these engagements, members and community partners emphasized the need for community-based makerspaces to partner with social justice organizations in working toward

gender and racial equity. This underscores the argument by Greene (2021) that technological solutions (such as makerspaces) to complex social problems (such as racism and sexism) are at risk of replicating the very problems they seek to address. As such, working toward racial justice requires mutual aid and widespread social movements that extend far beyond the walls of any single organization. As Foster (2019) has noted, feminist hackerspaces are positioned to do this work because they are organized around a politics of care and a commitment to prefiguring the worlds members need. This politics of care can be implemented in other STEM learning environments by centering the experiences of women and particularly women of color, by recognizing the rich, global histories of artisan and maker economies. This recognition can take the form of predominantly hiring skilled instructors from marginalized communities, honoring the lived experiences of women and communities of color as valuable sources of knowledge, and reclaiming craftwork such as weaving, ceramics, and sewing, as an essential part of STEM learning.

4.4.2 Ceding Space, Assuming a Reparative Stance

Reparations and resource redistribution were identified by interviewees as key elements of working toward gender and racial equity. Leadership and representation were further identified as key elements of working toward racial justice. Leadership and representation in terms of who serves on the Board of Directors and who is leading feminist makerspaces has a significant impact on who shows up as members and participants in these spaces. When cisgender white women are founders of a community project that aims to build gender and racial equity, those founders have a responsibility to center racial justice in the activities of the space

by supporting the work of Black-led racial justice organizations. By decentralizing leadership and instead taking direction from a diverse constituent base that is most impacted by sexism and racism, informal STEM learning environments can take part in furthering the greater social movement for gender and racial justice.

Furthermore, makerspaces must go beyond simply making objects and sharing tools (Brown & Antink-Meyer, 2017). Feminist makerspaces have demonstrated their ability to foster meaningful learning and a sense of belonging among female participants (Russo et al., 2021). Feminist makerspaces also have the potential to enable a nurturing culture that promotes learning through collaboration and individual agency (Kim et al., 2018) and to support learners in defining meaningful projects (Einarsson & Hertzum, 2019). In the context of informal STEM learning environments, scaffolded learning in the form of project consultation time following basic equipment training is one way to work toward building meaningful projects. For example, by hosting regularly scheduled "drop-in" project consultation hours with diverse instructors who represent the community that makerspaces aim to serve, participants can be supported throughout the entire creation process. This allows community members to define projects that are meaningful to them and be provided with the tools and resources to bring those projects into reality.

4.4.3 Confronting Harmful Compromises

Crucially, members of Prototype and its community partners emphasized the need for technical spaces to resist reliance on corporate funding. One aspect to be further scrutinized in the context of feminist makerspaces is the role of business incubators for entrepreneurial makers.

For example, historically in the U.S., foundations and nonprofits have been used to control Black social movements by integrating Black communities with American corporate capitalism which has resulted in the "continued corporate domination of Black communities by means of a new Black elite" (Allen in *The Revolution Will Not Be Funded*, p. 56). With the support of the community and broader social movements, feminist makerspaces can serve as a place to equip marginalized communities with the tools to both address current inequities and to collectively organize against these inequities. Across informal STEM learning environments, my research finds that there can be a stronger push to explain and critically examine existing economic structures as well as provide makerspace participants with alternatives to for-profit, hierarchical structures in entrepreneurship such as worker-led cooperatives. By fostering comradery and cooperation over competition, feminist makerspaces can be instrumental in transforming the technological spaces we inhabit.

4.5 Conclusion

In this chapter, I examined how feminist makerspace participants have worked to build coalitions, seek autonomy from corporate influence, and center racial justice in their work. Specifically, I found that being flexible in response to community needs is a necessary strategy for engaging diverse constituents and that informal STEM learning environments must marshal resources and programs that serve women of color. I have also found that creating a separate space for unlearning white supremacy culture among white peers is an essential part of doing racial justice work. Finally, I have found that feminist and racial justice work must extend across organizations and resist reliance on corporate or foundation funding which can change at any moment depending on institutional priorities and political climate. It is my hope that other educators and researchers who are working to address the 'gender filter' problem for women in

STEM might be moved beyond access and inclusion toward transformation of the technological spaces we inhabit.

5.0 The Role of Feminist Makerspaces in Building and Sustaining Alternative Cultures of Tech Production

5.1 Introduction

> [Our makerspace] can only ever be a node on the constellation of projects happening in [our city]. How it fits within social justice and racial justice projects is about relationships between people at [the makerspace] who have moved on. It's an ecosystem sensibility. (Anonymous Feminist Makerspace Co-Founder, 2020).

As the co-founder of one of the longest-running feminist makerspaces in the United States, this woman has dedicated her life to creating a cooperative workspace that centers the experiences of women and people with marginalized gender identities. For over 20 years, this space has operated on a mostly volunteer run basis while serving as an incubator for hundreds of artists, entrepreneurs, makers, tech workers, and activists. Along with other founders of feminist makerspaces, she finds herself grappling with questions of how these spaces fit within broader social justice projects and how to remain responsive to community needs over time. While there can be pressure from philanthropists and investors to scale these community-led spaces, I have talked with founders from across the United States and Canada about the importance of deepening relationships with other community organizations instead of scaling the operations of their individual organization. This ecosystem approach might help strengthen broader social justice projects while also contributing to the long-term sustainability of the organization.

Based on my interviews with some of the founders of these spaces, I have also found that financial troubles and widespread burnout among members were the most commonly cited reasons for their closure. At the same time, feminist makerspaces have been shown to foster feelings of wellbeing and empowerment among their members (Capel et al., 2021; Fox et al.,

2015). For this reason, the question of how feminist makerspaces can become sustainable movements is of increasing importance in the field of computer-supported cooperative work (CSCW) as women, people of color, and people with marginalized gender identities continue to experience rampant sexism and racism in the technology sector.

In this chapter, I focus on a key tension that emerged in my interviews with participants, which centers on coalition building versus an approach that places the onus of addressing sexism and racism in technology on one organization. I argue that an ecosystem approach is key not only for ensuring the sustainability of feminist makerspaces but also for building alternative cultures of technology production. I understand alternative cultures of tech production to be the community-based places and relationships that produce software, hardware, and technical knowledge. Often informal in nature and existing outside of large institutions such as tech companies and universities, alternative cultures of tech production can include hackerspaces, makerspaces, coding boot camps, open-source technology conferences, hackathons, and more. Many alternative cultures of tech production also value diverse ways of knowing which center anti-racism, feminism, and anti-capitalism, while challenging dominant technologies that replicate racist and patriarchal values.

To arrive at my argument that an ecosystem approach is key for sustaining alternative cultures of tech production, I draw on interview data conducted over six months as well as my own retrospective autoethnographic reflections on co-founding and managing a feminist makerspace for five years. In focusing on feminist and anti-racist forms of computer-supported cooperative work, this chapter contributes to the ongoing conversation of how equity-focused epistemologies can build and maintain alternative communities that challenge oppressive cultures while supporting women, people of color, and people with marginalized gender

identities in their personal and professional objectives. In particular, this chapter explores the following research questions:

1) How does an ecosystem approach strengthen alternative cultures of tech production?
2) How do feminist makerspaces contribute to larger social justice projects in their regional ecosystem?

From my interviews, I found that an ecosystem approach was a successful way to ensure the longevity of alternative cultures of tech production. In the context of feminist makerspaces, this ecosystem approach took the form of aligning with larger social justice projects, and racial justice projects in particular, as well as fostering long-term engagement among members.

To conclude, I discuss how prefigurative design can frame conversations and negotiate boundaries around the goals and expectations that researchers and practitioners have when it comes to collaborative work. Furthermore, I discuss the ways in which cooperative approaches to building gender and racial equity in technology require context-specific responses that acknowledge the many people, projects, and organizations involved in social justice work. Specifically, I find that when feminist makerspaces work along with other social justice organizations and focus on deepening existing relationships in their regional ecosystem, widespread burnout and short term engagement among participants might be avoided and the long-term sustainability of feminist makerspaces might be strengthened.

In addressing these questions, I offer three contributions to computer-supported cooperative work (CSCW): First, I examine specific practices that feminist makerspace participants enact to sustain their spaces. Second, I explore how promoting alternative tech production can strengthen regional social justice projects. Lastly, by identifying the coalition-building strategies taken up by some spaces, I offer a potential path forward for alternative cultures of tech production.

5.2 Related Work

I situate this study in two key bodies of scholarship that motivate and animate my work. First, I examine a growing trend of human-computer interaction research examining how the incentive structures of dominant tech institutions have contributed to the production of racist and sexist technologies and I look to Black feminist thought to explore what feminist and anti-racist approaches to technology production look like in practice. Next, I examine the work of scholars and activists alike who trouble the relationship between dominant tech institutions and oppressive power structures through counter institutions and prefigurative design strategies which seek to create more just worlds with and without tech.

5.2.1 Liberatory Design: Dismantling Oppressive Tech

Dominant values and norms are typically encoded in many technologies. Costanza-Chock (2020) discusses the reality that unless designers are specifically told otherwise, users are assumed to be middle class, white, male, able-bodied, straight, and to have reliable internet access. However, liberatory design challenges these assumptions about users and instead considers the relationship between design, power, and social justice. One approach to liberatory design is "design justice" in which marginalized communities challenge rather than reproduce structural inequalities by designing tech that serves the needs of community-based organizations and social movements (Costanza-Chock, 2020). One example of design justice in practice is when the LGBTQ community and drag queens in particular challenged Facebook's "real name" policy, since many members of this community choose to not use their given names. After flagging and suspending the accounts of many users from the LGBTQ community who were

suspected of not using their given names, Facebook changed course and allowed users to display their chosen names, as well as their gender identity and pronouns (Costanza-Chock, 2020).

Another approach to liberatory design is "data feminism" which considers the role of race, gender, and class in data science (D'Ignazio & Klein, 2020). Data feminism begins with an analysis of how power operates in the world, challenging these unequal power structures, and then working toward justice. By valuing multiple forms of knowledge and viewing knowledge as coming from people who are living, feeling bodies in the world, data feminism calls for elevating emotion and embodiment and giving priority to local, Indigenous, and experiential ways of knowing (Ibid). Data feminism asserts that no data is neutral or objective but that it is a product of unequal power relations. Shaowen Bardzell laid the groundwork for data feminism by outlining an agenda for design that employs feminist principles in human computer interaction. With a focus on the design process, Bardzell considers how feminism can inform user research, prototyping, and evaluation, by recognizing and utilizing the knowledge and perspectives that women have, rather than further marginalizing their perspectives (2010). By employing feminist design principles, tools and equipment can actually improve the lives of underrepresented groups in societies, by seeking out their perspectives and experiences, and elevating their needs to the forefront of the design process. Importantly, Bardzell emphasizes that the most important contribution of feminism to social science is standpoint theory which posits that all knowledge is socially situated and subjective, as opposed to neutral and objective (Ibid, 2010).

Sociologist Ruha Benjamin coined the phrase "the New Jim Code" to refer to the whiteness and racism inherent in many of the technologies commonly used. Benjamin cites a beauty competition judged by robots in which people from all over the world submitted selfies to an app that used a so-called "unbiased" algorithm but most of the winners were white. The

"Beauty AI" deemed white people to be more attractive than people of color and also argued that assumptions can be made about a person's health based on a photograph alone. The white winners, therefore, were judged to be healthy and fit, while those with darker skin were coded as unhealthy and unfit, assumptions which Benjamin emphasizes are at the heart of scientific racism and eugenic ideology and policies (Benjamin, 2019). Recognizing the racist and sexist context that creates oppressive technologies is the first step toward dismantling them.

Another necessary step in dismantling oppressive tech is valuing multiple ways of knowing. Informed by the unique lens with which Black women navigate society, sociology scholar Patricia Hill Collins presented a theoretical framework which considers the relationship between race, gender, and class, and how individuals who have multiple marginalized identities navigate compounding oppressions. While each dimension of identity is treated as a separate social classification, these dimensions are interlocking and different combinations result in vastly different forms of oppression (e.g. the "matrix of domination"). This theoretical framework is, as Patricia Hill Collins stated, built on a lineage of Black feminist thought. The development of Black feminist thought entailed applying new theoretical frameworks to existing works to facilitate reinterpretation, searching within alternative institutions for the expression of thought by Black women, and reclaiming and surfacing Black women's ideas which have been systematically silenced and erased. Black feminist thought provides a framework for understanding the importance of alternative sites of knowledge production outside of white, male-dominated institutions which have systemically silenced Black women. Such a framework is essential for this work, where I consider how feminist makerspaces build on a tradition of creating alternative cultures of tech production.

Erete et al. (2021) build upon Black feminist thought in human-computer interaction (HCI) and CSCW by using autoethnography to reflect on their personal experiences of racism in the academy and throughout society. These personal testimonies serve as a refusal to remain silent about racism in tech as well as advocacy for more inclusionary politics for Black women in HCI and CSCW. Specifically, the authors discuss how top technology companies discriminate against Black women who graduate from Historically Black Colleges & Universities (HBCUs) and how these racist hiring policies reflect a broader hostile culture directed toward Black women and other women of color. The authors tell personal stories of how even when Black women are hired in tech companies and computer science university departments, they are still subject to hostile work environments. In this way, Erete et al. use standpoint epistemology to claim their lived experiences as valid sources of knowledge situated within the racist social context of the United States which has a history of slavery and segregation as well as ongoing systemic racism through institutions such as prisons, policing, and schooling. The space that Black feminist scholars in technology take up through writing, speaking, producing work, and researching is one example of an alternative culture of tech production. In this context, Black feminist writing in HCI and CSCW is an alternative to the white supremacist norms found throughout U.S. institutions of higher education.

Further building upon this lineage of Black feminist thought, Rankin et al. (2021) discuss how Black women in computer science experience saturated sites of violence at the K-12 level and within predominantly white institutions. In both of these sites, Black women describe their experiences of being treated as though they don't belong, being stared at, and seeing surprised looks on their colleagues' faces when they show up to work and class. The assumptions and narratives that white people have told themselves about Black people constitute a "wall of

whiteness in CS" and this creates a hostile and discriminatory environment for people of color and Black women in particular within institutions of higher education (Rankin et al., 2021). Naming the specific processes that create these environments – that is, white people perpetuating hostile and racist narratives about Black women in tech - is one way to begin challenging the white supremacist culture within CS departments in universities.

Relatedly, Vossoughi et al. (2016) argue that equity oriented design and research must begin with a clear analysis of educational injustices and how they shape the lived experiences and pedagogical needs of learners and their communities. Specifically, the authors call for an explicit analysis of injustices in STEM rather than efforts to broaden participation of underrepresented students in STEM. Increasing access to makerspaces and STEM learning environments as they currently exist in many institutions, is not sufficient for bringing about equity. Instead, the authors call for "collective reimagining and transformation of the system itself" (p. 215). In this next session I turn toward strategies that scholars and practitioners are using to imagine better and more equitable technologies.

5.2.2 Prefigurative Design and Counter-Institutions

Prefigurative design and counter-institutions have common principles such as liberation, anti-oppression, and dignity, as well as actively engaging participants in negotiating and deciding on outcomes that best represent their needs (Asad, 2019). Specifically, Asad calls for all design to begin with affected community members naming who is being harmed and by whom, imagining what healing looks like, prioritizing needs, marshaling resources to support healing, and employing interventions that support healing while minimizing harm. As such, the role of

counter-institutions in prefigurative design is for people who are most directly impacted by injustice to create structures for community that allow for autonomy and control. For example, communities of practice are groups of people who share a passion about a topic and who deepen their knowledge in this area by interacting on an ongoing basis (Baker & Beames, 2016). In particular, communities of practice dedicated to cooperative work might contribute to the solidarity economy, which can be thought of as a counter-institution where there are networks of mutual aid, defined broadly as informal, collective structures of support which address the needs of citizens when institutions fail to provide adequate support (Spade, 2020).

In a case study of sex workers who developed their own tool to identify "bad clients and aggressors" by creating a list of perpetrators, Strohmayer (2017) explores how digital technologies can promote social justice. In an area of work that is often criminalized, this tool developed by sex workers allowed them to report violence while maintaining anonymity and without resorting to calling the police. The authors conclude that designing for alternative forms of justice must be key in any social justice HCI project and specifically that not all technologies should be generalizable and easily translated to different contexts. Instead, context-specific technologies such as "the list of bad clients" developed by sex workers can protect marginalized groups. Specifically, the authors argue that, "nuanced and justice-oriented design of digital technologies can be made possible if we start to see technologies not as solutions to complex social problems, but rather as aides that can support the humanity of service delivery and the people who engage in this kind of work" (p. 652). Context-specific technologies that make marginalized communities more safe is a crucial example of critical HCI in practice.

In addition to sex workers creating their own technology to promote social justice, there is a growing number of instances where individuals historically subjected to harm by tech take

matters into their own hands. In the context of artificial intelligence approaches to facial recognition, Black feminist scholars have led a movement to outright deny these technologies by wearing masks (Buolamwini & Gebru, 2018). Other activists have damaged cameras in public spaces as a way to refuse to engage with harmful facial recognition technologies. This movement by scholars and activists has led to the closure of Facebook and Amazon facial recognition technologies as well as a growing call from the human-computer interaction community to produce technologies that do not cause further harm to women and people of color.

Marginalized people from many different communities continue to argue for the creation of technologies that validate and support their experiences. Afrofuturism is a social movement that centers Black communities both in the present and in imagining the future (Dery, 1997). Specifically, speculative participatory design is one approach that is taken to move away from designers and experts and instead frame design as being community driven particularly by considering the lived experiences of Black and brown communities (Bray & Harrington, 2021). Other scholars have centered the experiences of queer communities by considering how voice assistants like Alexa understand queer voices and account for domestic relationships among queer couples (Kinnee et al., 2020). Centering the experiences of transgender and non-binary people in one design study found that more technologies are needed to support changing appearances, changing bodies, safety, and finding resources (Haimson et al., 2020). By putting transgender and non-binary people at the center of the design process, technology becomes more inclusive by focusing on the connection between community members and on the resources they share amongst one another (Ibid, 2020). Still, other scholars advocate for centering the experiences of low-income students of color who are often subject to discriminatory artificial intelligence tools that are largely created by white, male software developers and which use

decades of biased educational data that does not take into account the socioeconomic conditions that create unequal test scores, graduation rates, and overall school performance (Gaskins, 2022). This algorithmic bias, when not accounted for, can further entrench inequities in schools. However, by centering the experiences of Black and brown students in the software development process, it becomes possible to make culturally relevant technologies that create the conditions for liberation.

Another way that scholars have taken up the idea of counter-institutions is by creating equitable ecosystems through training community members to map out their local resources using geospatial technologies. Erete et al. (2020) describe a process called "Community Conversations" in which community members are central to the process of designing an equitable learning ecosystem using geospatial technologies. In this process, researchers create data visualizations of community demographics including unemployment, race, income, and crime. With these visuals, researchers then meet with community service providers to add supplemental data that helps to explain the baseline data. For example, if crime is concentrated in a particular area, youth workers and violence prevention workers might be able to describe where there is a lack of out-of-school time programs for youth to engage in. Feedback from community members, for example, might also highlight a lack of coding programs available to youth or a lack of transportation for youth to get to coding programs. This "on the ground" data is used to supplement the researcher-supplied "baseline data" and then this combined data is presented to community members for their insight.

Other counter institutions that exist include a community space in Australia where researchers studied how environments that enable women's participation can employ storytelling and making to address barriers to participation in broader makerspaces (Capel, 2020).

Specifically, participants worked with wood and other materials typically found in male-dominated makerspaces, and while working with these materials carved into wood and verbally shared stories about the making practices they have previously engaged in, as well as practices that they never had access to, and how these workshops contributed to feeling empowered (Capel, 2020). Themes that arose from the participants' stories included housing insecurity, health problems, and relationships. By creating a space for women to share their stories and lived experiences, the community center was able to make historically male-dominated practices and materials accessible to women.

Creating equitable regional ecosystems with marginalized community members at the center might be one way to drive sustainable HCI that does not rely on a few sources of support but instead strives to be truly community driven. Throughout this chapter, I understand sustainable HCI as human-computer work that considers longer time scales and that builds upon and supports systems that people use in their everyday lives (Silberman et al., 2014) as well as technology that addresses collective and regional policy concerns over individual consumer issues (DiSalvo et al., 2010). Furthermore, I revisit the theoretical lens of learning ecosystems to describe how community organizations such as feminist makerspaces create equitable learning experiences, technologies, and design approaches, in partnership with other community organizations and social movements. Learning ecosystems in this context helps us to see that creating equitable technologies is not just the business of designers and scholars, and that community members who are most affected by racism and sexism must be at the center of creating sustainable counter-institutions, design approaches, and technologies.

5.3 Methods

To investigate my questions, I took a qualitative, ethnographic approach which also draws on interpretivist perspectives in which researchers aim to translate rather than transcribe social phenomena (Miles, 2018). I considered how my position as a researcher and graduate student at a major public institution in the United States might influence my analysis. I also considered how my identity as a cisgender women in my mid-thirties might influence my research and interview analysis.

I started the process of reaching out to feminist makerspace founders in March 2020 just as the COVID-19 pandemic was becoming a reality. As such, I did not travel for any of the interviews, and all interviews were conducted over virtual meeting. I focused my outreach on organizations that describe themselves as makerspaces or hackerspaces and as having either feminist or anti-racist values in their mission statements. I secured interviews with founders by emailing them (some email addresses were listed on the makerspace websites and other email addresses were given to me by people I know who have been members in those makerspaces). For example, some of the makerspace members at a local organization had previously lived in other cities and had been members at other makerspaces, so they had personal connections with those makerspace founders and members.

I conducted interviews with co-founders, founding members, and current members of makerspaces and makerspaces from Toronto, Canada and seven cities across the United States: San Francisco, Seattle, Berkeley, Oakland, Portland (Oregon), Pittsburgh and Providence. In total, I spoke with 17 people representing 9 feminist makerspaces, some of which are still in operation and others which are not. The organizations were all founded between 2000 and 2013. Three of the organizations (two in Portland and one in Seattle) are no longer in operation. Six of

the organizations (Toronto, Providence, San Francisco, Oakland, Pittsburgh, and Berkeley) are still in operation as of 2022.

Some of the members I interviewed describe their spaces as self-organized collectives that support women artists. Other makerspace members say that they created their space as a response to the questions, “Where are the women, the people of color, the queer folk, the blue collar workers? Where are our trusted allies?” [Withheld for peer review]. Still, other spaces have the explicit goal of fostering a creative safe space for women and nonbinary people, while being “people-of-color led, gender-diverse, queer and trans inclusive” [Withheld for peer review]. Although there were differences in how these makerspaces self identify and describe their activities, they all share the common goal of providing shared space, tools, and skills for community members.

Interviews lasted 60 to 90 minutes and followed an interview protocol in which I introduced myself as a feminist makerspace founder and as a researcher of feminist technologies. I told interviewees that I am conducting a study on the motivations, ideals, and activities of those who are organizing or participating in maker activities. I also asked for permission to record the interview for the purpose of audio transcription, and I explained that all information shared with me would be confidential.

I opened the interviews by asking participants to describe their background, which I intentionally left open-ended. Interviewees discussed their academic background, careers, ethnicity and racial identity, gender identity, and economic background. I then asked what motivated them to get involved or start a makerspace with an explicitly feminist and anti-racist mission, and I asked participants to describe how their involvement has changed over time. I was also interested in capturing stories of the challenges that feminist makerspace members have

faced throughout their involvement, how they addressed these challenges, and I specifically asked participants, “If you could change one thing tomorrow about the space, what would it be?” Finally, I asked interviewees to describe the values and ideals of their makerspaces, with a particular focus on racial justice and the degree to which they have seen racial justice enacted through the activities of the space.

5.4 Findings

I found three main themes across my interviews with makerspace founders including: 1) the double-edged sword of short-term investments; 2) the importance of depth over scale of relationships, and; 3) fostering connections with local community members instead of hiring outside consultants to do equity work. Each of these findings points to a grassroots approach which allowed members to persevere in creative ways and in some cases to even survive against the odds.

5.4.1 Double Edged Sword of Short-term Investments

Among the founders I interviewed, most said that wealthy founding members were involved in initially supporting the organization through charitable donations. These donations were typically made by members of the makerspace who worked in the tech sector, had significant disposable income, and did not expect to be paid back for their contribution. Members were motivated to underwrite the initiative because they wanted to create a space that felt safer

and more supportive than their tech jobs and they had the income to make it possible. As one founding member of a San Francisco-based space recalls:

> Three or four of us decided, if this goes south and no one joins, we can afford to pay this for a year.

This interviewee is emphasizing the critical role that founding members often made in short-term investments to open up new feminist makerspaces. However, these short-term investments did not come without disagreement and conflict. As a founding member of another west coast-based space notes:

> Beth[4] found a space and jumped on it but Juan was a communist and was upset that she didn't consult with him. As more money trickled into [the city], there were less spaces we could afford. It was hard to find a space that was accessible and easy to get to from public transit. I had a software job and was able to make a big investment.

This founder is highlighting the double-edged sword of tech money which often meant that new spaces could open because of the individual investments made by founders who worked in tech. Across my interviews with founding members of feminist makerspaces I observed this trend of individual members carrying the weight of the organization, both financially and in terms of personal time and energy, and this leading to short-term engagement and burnout. Whether these short-term investments were in the form of financial investments of founding members who work for tech companies, philanthropic donations directly from tech companies to feminist makerspaces, or a few founders taking on a majority of the work of running an organization, these initial investments were helpful at first but were ultimately not a sustainable source for maintaining the organization because they were a one-time donation. Based on my interviews I also saw that investments from tech companies into community projects as well as

[4] Pseudonyms are used throughout this chapter

the personal investments made by founders who work in tech often eventually contributed to displacement and gentrification of the neighborhood surrounding the makerspace. While the neighborhoods that many makerspaces opened in were initially affordable, over time they became inaccessible to lower income communities.

Additionally, while founders spoke about their desire to create a community that was not reliant on corporate revenue, and that enacted anti-racist and feminist practices, unfortunately these good intentions could not always outweigh the burden of managing a legal entity. These burdens and legal obligations include annual tax filing, paying for and maintaining good standing with an insurance company in order to be covered by liability insurance, and managing a Board of Directors with all of its committees, meetings, and agendas. In short, managing a nonprofit organization requires resilience and long-term commitment that is difficult in any situation but particularly difficult when there are not enough financial resources to compensate founding members fairly for their time and energy.

This challenge - of needing to be a good steward of the legal obligations involved with running a nonprofit organization while not having sufficient funding to pay people to be good stewards - was a frequent theme in my interviews with founders. One founding member from an east coast-based space spoke about the turnover inherent in the Board of Director committees:

> It used to be four formal roles on the steering committee: membership, finance, programming, operations. But it was really hard because it ended up being a lot of turn over…once something becomes more established, it's like people don't want to be part of it anymore. I think a lot of how [this makerspace] functions is like an incubator, where people realize what they want to be a part of, and then they go somewhere else to focus on it.

What this founding member describes is the initial excitement and energy that often surrounds starting a new project or founding a new space which can then dwindle when founders

are faced with the often bureaucratic and tedious aspects of maintaining the organization over time. Furthermore, this founder spoke to the idea of her feminist makerspace not serving as an end-all for members, but instead for the space to serve as an entry point and incubation period for people who care about equity, design, and tech. This entry point was often a low or no barrier for people to get involved in nonprofit organization management, and once members felt as though they were ready to move on, they joined larger and more established organizations. In other words, this feminist makerspace served as an incubator for participants to gain nonprofit management experience as well as social justice organizing skills.

Based on my experience of founding a feminist makerspace that has developed its own governing policies and bylaws, I am aware of the process involved with creating and maintaining a Board of Directors that guides the work of the organization and sets its strategic goals and direction. The founders I spoke with were often unfamiliar with these processes in the early days of their organizations. In the context of smaller and younger organizations, it is particularly common for founding members to serve as part of a "working board" or committee where members take on the responsibility of managing many of the organizational aspects for which staff people would often be responsible. However, because of the lack of staff people, unpaid founding members and Board members in these smaller, less established organizations must take on more operational tasks such as paying bills, updating the website, coordinating open houses, maintaining equipment, taking out the trash, sweeping floors, and other similar tasks that require daily and weekly upkeep.

High turnover as a result of board members and unpaid founding members being tasked with time-intensive and staff-like responsibilities is a common reality for feminist makerspaces. This high turnover is also related to the frequency at which feminist makerspaces recruit new

members to join the Board of Directors. This was a common theme in my interviews; of founders recruiting new members to join the Board of Directors, even though they were relatively unfamiliar with the organization and did not join with the intention of leading it. As one Director recalls:

> It was June last year when I joined and only a few months later, in September or October they were looking for new [board] members, a call went out on the listserv. As someone who works in nonprofit development, I work with board members and I've been curious about what it would be like to be on a board of an organization. Looking for a low financial commitment to get into that so it seemed like perfect timing. Did a couple meetings with the current board members, and they didn't mind that I didn't know what I was doing because that's the spirit of this whole thing.

As this new Board member describes, she had only been involved in the makerspace for three or four months when she was asked to join the Board of Directors. Because she was not able to contribute financially to the organization, she saw this leadership opportunity as a way to learn more about what it means to serve on a Board of Directors for a nonprofit organization. Importantly, she also felt welcomed and encouraged to join despite not having the requisite knowledge. However, this raises the question of how long new Board members continue to feel supported after joining the leadership of an organization.

In fact, many of the founders I spoke with left the organization after one or two years, while often leaving the legal and financial responsibilities of running a nonprofit organization to new members who were unfamiliar with the Board of Directors role but who were eager to help out nonetheless. Based on my experience of founding and maintaining a feminist makerspace for five years, I understand that institutional knowledge is a key part of running a successful organization and without it, many nonprofit organizations are doomed to fail. While the initial vision and momentum of these spaces was set by a team of founders, there was less cohesion in the organization once founders cycled out.

One potential avenue for organizational sustainability and financial stability identified by makerspace founders was through grant making programs such as local economic development efforts led by large philanthropic institutions and local government. However, this was also seen as a challenge by members since most of the makerspace founders I spoke with were anti-capitalist and volunteers. This was a central theme in my interviews: there is an ongoing tension in feminist makerspaces to create a validating and empowering community for women and people with marginalized gender identities without accepting funding from technology corporations and philanthropic organizations in doing so. According to one makerspace founder:

> Our biggest problem is financial. It's hard to raise money when we don't want to charge people to use the space. Our biggest challenges are on finances and capacity for people to do the organizing. We don't want to ask Google or Facebook for money.

This tension — between wanting to provide a community resource at an affordable cost while also not wanting to accept corporate donations or philanthropic funding — was a common theme in my interviews with founders. Not only did founders view corporate and philanthropic funding as coming with time-intensive reporting and obligations that they did not have capacity for, there was also reluctance and hesitation on behalf of founders in being associated with tech companies. Instead, the founders I spoke with emphasized the importance of being financially accessible to members, and not charging community members for space rental, particularly for progressive political meetings and community events.

In my own experience of founding a feminist makerspace, we were offered a large grant from a technology company in our first two years of operation. Because we needed the money and did not yet have decision making processes in place, the two co-founders decided on behalf of all members to take the money. While this money allowed us to expand the space, purchase equipment, and hire a staff person, it alienated some members from the space who initially saw it

as an anti-capitalist and collective effort to reimagine tech. After the funding ran out in one year, the space was unable to sustain the salary of the staff person and their contract was not extended. Furthermore, the space struggled to pay rent for its expanded location and had to begin a membership campaign to attract new members and diversify revenue streams.

Another way this tension revealed itself in other spaces was that many founding members had a desire to take ownership over the buildings that makerspaces are housed in. This desire connects to a larger movement for community land trusts and the solidarity economy which positions communities as having collective wealth and power in opposition to capitalist and individualist modes of ownership. As one founder noted:

> We didn't take donations for the most part. We were mostly supported by the community and we had organizations who were working out of the space as our co-tenants and sublessors.

This makerspace founder emphasized how donations were not accepted from any organizations and instead a type of collective rent paying has sustained the space. Across the interviews I found that makerspaces that have managed to remain open have either a monthly recurring membership model or sub-tenants who bring in regular income to the space.

5.4.2 Depth Over Scale

Across these interviews I noted that feminist makerspaces which have persisted over time often take a collective survival approach to sustaining themselves, one in which donations are not solicited from large tech companies, many members are involved in the maintenance of the space, and community members are integral to its operations. Furthermore, I noted that focusing on the depth of relationships among founding members versus scaling the organization was

critical to organizational sustainability. In particular, developing decision making processes and slowing down to discuss shared values as well as potential political misalignments among members was key to the long-term success of these organizations.

Although financial instability, short-term engagement and burnout were common themes among the founders and members we spoke with, there were some ideas around how feminist makerspaces can be sustainable. In fact, one of the makerspace founders we spoke with, who has been directing this makerspace for more than 20 years, discussed the importance of community-level relationships in ensuring the financial stability of the makerspace:

> We don't want to get any bigger and we don't want to do any more. If it's bigger, it should be about depth of relationships. I think that's a value. There's a lot of pressure in the nonprofit community to always grow, grow, grow. But you can say, no that's enough. Whatever comes next has to be about deepening and strengthening.

In this particular east coast-based makerspace, financial sustainability resulted when the makerspace decided to stop expanding its physical building and programs and instead focus on paying its two co-founders and investing in its artists-in-residence. This was primarily achieved by renting out its building to artists as tenants. Similarly, the founder of a west coast-based space emphasized the importance of community building:

> I wanted to give people an opportunity to use tools they couldn't use at home, promote social events, and create a space for people to talk to each other. In all the projects that I keep talking about they all have to do with third space.

This 'third space' refers to a space that is neither work nor home. However, the desire to have a space that is located in an affordable neighborhood was often at odds with the realities of gentrification and the displacement of lower income communities. While many of the makerspaces I examined were located in industrial neighborhoods, these same neighborhoods often have complicated histories. According to one founding member:

> We moved out of our space [in a central neighborhood] and are now on the outskirts in a neighborhood with complicated racial dynamics. There is public housing where parts of it are being torn down and being rebuilt. It's a somewhat industrial neighborhood but it's [an expensive city] so the nonpublic housing is wildly expensive.

Many makerspace founders discussed how they negotiate this tension of existing in a neighborhood where lower income residents are being displaced as commercial tenants move in with wanting to have an affordable space that does not contribute to gentrification. One founder discussed the importance of centering people of color in the space and taking direction from communities of color in the neighborhood:

> What cultural shifts need to happen in order to switch over from being a space where there are some POC who feel comfortable and have made projects here to investing in projects in our community that are POC led.

Rather than simply being a space that is inclusive for people of color or that has racially diverse membership, this founding member emphasized the importance of stepping outside of the space to take direction from POC led projects in the community and to make the space relevant to their needs and interests.

One particular makerspace was located in a high poverty area and next to a women's shelter. As this founding member further recalls:

> Dana was homeless and living in a shelter, going to code school, and using [the feminist makerspace] as a springboard to do some outreach for the community. Dana is a Black trans woman. She was getting women to apply and come to the space, running events.

Dana thought that forging connections with their neighbors who were part of racial justice POC led organizations would be a straightforward and sustainable approach to attracting members. To put this practice into policy, I found that some feminist makerspaces created codes of conduct about who can join the space. For example, rather than creating a space that is

radically inclusive of anyone, one makerspace founder discussed the need to prioritize and explicitly welcome underrepresented communities:

> When I think about the [makerspace] code of conduct it's a shift in priorities from let's be a cool hacker iconoclast and break stuff to what is this space that we're allowed to participate in, where people are underrepresented in other communities are explicitly welcomed. That was the radical thing about feminist makerspaces and hackerspaces was that fundamental shift. It's not actually possible to include everyone, you can't, so being deliberate about who you're choosing to include.

Centering the experiences of people of color and people with marginalized gender identities is one way to decenter dominant, white, and heteronormative ways of producing technology. This emerged as a common theme across the interviews. Some co-founders spoke about the need for feminist makerspaces to challenge the gender binary:

> Cis-feminism I'm not finding to be particularly useful for understanding trans issues. I transitioned at 30 and feel a different connection to different genders at different times. Like men are trash! But what about trans men?

This founder spoke about their experience transitioning as a trans man while managing a feminist makerspace and how their perspective on who should be centered in the work changed as well. Specifically, as they came to identify as a trans man, they no longer felt it was helpful to center cis women in feminist makerspaces. All of the founders I spoke with were similarly grappling with how to challenge a gender binary that is inherent in larger societal structures and institutions while running a space that exists within this sociopolitical context. This is where the counter-institution comes into practice: founders addressed this challenge by slowing down, deepening relationships among members through intentional decision making processes, and creating codes of conduct that center people of color and people with marginalized gender identities.

5.4.3 Centering Lived Experience

Across my interviews there was a central theme of founders doing critical diversity, equity, and inclusion (DEI) work in their organizations by valuing local community members for their lived experience and expertise with issues of equity. In one makerspace, founding members discussed how to do meaningful DEI work in the space over the member email list:

> There was a question on the list about what are we doing about diversity and inclusion. I wrote back saying, we are in this building which is very heavily POC led organizations. Why don't we talk to our neighbors, invite them into our space, and operate this way, it's extremely easy.

A similar strategy was developed by Prototype members during our founding. In our cooperatively run building that was racially diverse, POC tenants proposed a decision-making structure that would give additional weight to votes made by POC when the building tenants came together to make decisions that would affect all tenants. This was accepted by the rest of the tenants and it became the policy for decision-making during all building-wide meetings.

In my interviews with founding members of makerspaces, I saw that when racial justice is not named as a core value of the space from the very beginning, such spaces often become predominantly white and do not reflect a vision of racial justice. As such, an ecosystem approach that is rooted in solidarity with POC-led racial justice organizations can be one way to interrupt the white and macho tech world. According to one founder, whose space is led by people of color and primarily serves communities of color:

> I remember going to events like Maker Faire and meeting lots of people who were excited and passionate about making. But it wasn't a very diverse group and a lot of people were being professional makers by rediscovering traditional arts like learning how to ferment, learning how to sew. These are things in our community that people have as part of their traditions. Sewing in particular. Women of color get paid below minimum wage. And then you have people at Maker Faire who have learned sewing relatively

> recently who are making a decent living doing it but probably with less skill. I was really struck by the disparity there. Making felt like a rebranding of something that a lot of communities of color already do.

I spoke with another makerspace founder who expressed a similar sentiment. This makerspace founder, whose organization is POC-led, defined maker activities as coming from a place of necessity:

> When I think about makers, I think about my fellow Chicanos. My friend from high school who was too broke to build his own computer case so he built one out of wood.

According to this account, maker activities are born out of necessity and not out of compliance to the dominant and harmful tech culture. Similarly, another feminist makerspace founder recalls their motivation for seeking out an alternative community of technology production:

> I've been to a few makerspaces in [east coast U.S. city] and [west coast U.S. city]. The [east coast U.S. city] one was better than the ones I was part of in California. The one in California, I was given a tour of the facility, and the guy was like, "Oh this is the rape room." That instantly frightened me. That type of culture was all males, they were very into their rooms, it didn't feel welcoming, I felt like they were trying to deter me.

Accounts like this one demonstrate the need for equity-centered technology spaces that create comfortable and safe environments particularly for women, queer people, and trans people of color. Similar stories of sexist and racist experiences were widespread among the feminist makerspace participants we spoke with. They point to the reality that mainstream cultures of tech production are often harmful toward women and people of color and that there is a need to sustain and grow projects that build systems of support and liberation.

Among the founders I spoke with, one discussed the importance of living and working alongside other artists in an illegal squat as contributing to the founding of the makerspace:

> I was really interested in the experiment of living and working alongside other artists. I couldn't have imagined at the time what form that would take but I was still in school when we started the [makerspace]. I wasn't actually thinking about how things would be different when I was out of school but I was already laying the foundation. Even my community and peer group, a lot of it was outside of the institution.

This community of support was a central theme in my interviews. For another founding member, the crossover of interests that was represented in the makerspace was a key reason for her joining:

> I truly didn't understand how important [the makerspace] was going to become to me back in 2014. There was a woman there who was finishing her PhD in computer science, other women not just in tech but a jewelry designer, or someone doing laser cutting work. It was a really cool group of people where I could get some support.

This cross section of computer scientists, parents, jewelry designers, and people using the laser cutter, provided a rich and diverse community. As scholars have noted, feminist communities are well positioned to support members because of their approach toward mutual aid and their active politics of care (Foster, 2019).

5.5 Discussion

5.5.1 Collective Survival

Throughout this chapter, I have examined specific practices that feminist makerspace participants enact to sustain their spaces. I have also explored how promoting alternative technology production can strengthen regional racial justice projects. Lastly, by identifying the coalition-building strategies taken up by some spaces, I have offered a potential path forward for alternative cultures of tech production. Importantly, this path involves feminist makerspaces taking on social and political work with their (literal and figurative) neighbors through coalition

building and viewing their work as part of a larger regional ecosystem in order to ensure collective survival. In particular, using an ecosystem approach to furthering gender and racial equity in technology can help feminist makerspace founders strengthen relationships between organizations doing similar work. Although there is often pressure from philanthropic organizations and corporate donors to grow existing programs, begin new programs, or expand the reach of an organization, the founders I spoke with emphasized that the sustainability and longevity of their spaces is actually dependent on having fewer but deeper relationships with existing members and community organizations. Instead of partnering with more organizations and attracting more members, founders have discovered long-term success in viewing their spaces as part of a larger ecosystem. Feminist makerspaces cannot solve every problem that exists in the larger technology and arts communities, however, through the depth of existing relationships with other community organizations, founders of these spaces can take an ecosystem approach to addressing the systemic problems of sexism and racism.

5.5.2 Retracing and Remaking Tech

In retracing and remaking alternative cultures of technology production, feminist makerspace founders might look to critical DEI to ensure that their efforts are equitable. This can be done by 1) viewing diversity and inclusion as a means, rather than an end, 2) providing the necessary support mechanisms for people engaged in diversity work, and 3) creating a detailed account of the justification for a particular institution to have a diversity initiative (Ahmed, 2014). Whereas one perspective among the makerspace members we spoke with emphasized the importance of the organization tackling its problem of lack of diversity by hiring consultants,

other members pointed to the need of working together with POC led organizations that work in close proximity to the makerspace. While the former perspective can be seen as a single handed approach, the latter perspective can be seen as a cooperative approach that recognizes the power of ecosystems in dismantling oppressive structures.

Furthermore, the politics of care that is alive in feminist makerspaces can be extended through a larger ecosystem by partnering with other social justice organizations. I imagine feminist makerspaces contributing to rethinking and prefiguring the future of tech by serving as counter-institutions that center marginalized voices. Specifically, feminist makerspaces ought to be involved in naming the harms caused by predominantly white institutions (PWIs), creating spaces of healing for Black women and other women of color, marshaling resources to support these women, and developing interventions to support women in tech. In imagining a more just future of tech, feminist makerspaces might build and sustain alternative cultures of tech production by partnering with and taking direction from organizations that center LGBTQ communities, women of color, people experiencing homelessness, formerly incarcerated women, and other marginalized communities. In doing so, these partnerships have the potential to create broad scale mutual aid in which communities are supported in creating and disseminating their own media, art, and technology. These partnerships might help feminist makerspaces become part of a larger effort to create equitable regional ecosystems with marginalized community members at the center. This might also be one way to drive sustainable HCI that does not rely on a few sources of support but instead strives to be truly community driven.

5.6 Conclusion

In this chapter, I investigated the long-term sustainability of feminist makerspaces and how they contribute to larger social justice projects. I have found that when feminist makerspaces are unable to financially sustain themselves, there is a risk of becoming reliant on funding from outside sources such as tech companies and wealthy individuals who work for tech companies. However, I also found that within the context of community-based cooperative work, prefigurative design can frame conversations and negotiate boundaries around the goals and expectations that researchers and practitioners have for feminist makerspaces. Specifically, prefigurative design provides a framework for identifying who is being harmed and by whom, what healing looks like, prioritizing needs, marshaling resources, and providing interventions while minimizing harm. When feminist makerspaces deepen existing relationships in their local community, build coalitions, and create counter-institutions with other social justice organizations, equitable ecosystems can be strengthened and sustained over time.

6.0 Toward Intersectional Feminist Networks of Support

Throughout this dissertation I have worked to uncover what is known about the nature and power of collaboration and coordination among the people, projects, and organizations working to facilitate equitable learning experiences with a focus on education networks and feminist makerspaces. I have found that education network engagement for members might contribute to validating their professional identity and helping them learn how to center equity in their work. Relatedly, I found that when feminist makerspace members take an ecosystem approach - deepening existing relationships in local communities, building coalitions, and creating counter-institutions with other social justice organizations - the longevity of their spaces can be strengthened and their coalitional work toward gender equity and racial justice can be further realized.

Across these four studies I found several key similarities between ecosystem approaches to education and feminist coalition building. These similarities include centering marginalized learners and educators in the work, partnering across organizations to create systems level change, and providing participants with pathways to become increasingly involved in social justice work. Furthermore, the organizing approach taken by education networks is one that places power and autonomy in the hands of members. In many ways, feminist approaches to coalition building and learning ecosystem approaches to education have the potential to subvert hierarchical modes of social organizing which places the power of decision making into the hands of a few people at the top. Education networks are collaborative, member-driven, and many are committed to advancing equity. Similarly, feminist approaches to coalition building

seek to break down silos across social justice organizations, while taking direction from membership (Yasmeen, 1990). Just as education networks have the potential to shift resources toward underfunded schools and community organizations, feminist approaches to coalition building can be involved in marshaling resources to support Black women and other women of color, and developing interventions to support women in STEM.

Although there is currently a gap in the literature as it relates to feminist approaches to ecosystem building, the participants interviewed throughout this dissertation demonstrate that this work is being done in practice. I continue to be inspired by the work of Dirt Palace in Rhode Island, Hackers and Designers in Amsterdam, Mz Baltazar's Laboratory in Vienna, and Flower House in Pittsburgh whom I have been grateful to work with over the last several years and whose work demonstrates what it means to enact an intersectional feminist learning ecosystem. In the remaining pages of this dissertation, I will describe an intersectional feminist network of support that I was involved in with a local artist in the summer of 2022. I share this work because I believe that it represents an intersectional feminist network in action. The following narrative explains and ties together the findings of my dissertation studies by demonstrating: 1) What feminist coalitions across organizational silos and even international borders might look like; 2) How educators can be responsive to community needs, and; 3) How informal STEM learning environments might marshal resources and programs that serve women of color.

6.1 A Vignette to Explore the Work of Naomi: Centering Lived Experience, Depth Over Scale, and Collective Survival

In the summer of 2022, my long-time friend Naomi and I decided to partner on a summer workshop series in our home city of Pittsburgh. Naomi was organizing a soccer program series

focused on moms and aunties with a focus on Black women. I was in conversation with the founders of Hackers and Designers in Amsterdam as well as Mz Baltazar's Laboratory in Vienna, which both identify as feminist makerspaces, about a workshop series they were organizing around the theme of solar punks. The solar punk movement can mean different things to different people but to Naomi and me, it meant exploring open source technologies and promoting collectivist approaches to learning.

Figure 5 Naomi Teaching a Lamp Assemblage Workshop at Prototype in 2017

Naomi and I have been friends for the last 10 years, but we first met as elementary school students at Woolslair Elementary more than 25 years ago. It was here that Naomi and I met as eight-year-old girls, from different neighborhoods, different racial backgrounds, with a common love of learning. As adults, Naomi and I reunited at Woolslair Elementary completely by chance

when we became robotics teachers in the afterschool program that Remake Learning was organizing. We were instantly drawn to one another and had an incredible experience teaching elementary school students the basics of computer coding, robotics assembly, and circuitry design.

Figure 6 One of the Projects Naomi and I Have Worked on Together: City as Our Makerspace in 2018 Which Focused on Uplifting Black Women Through Entrepreneurship and Makerspace Training

Over the next few years, Naomi and I partnered on several projects together including City as Our Makerspace, which was a series of workshops designed to engage Black women in conversations about healing from the effects of intergenerational poverty and trauma, financial planning, makerspace equipment training, and the basics of entrepreneurship. The vision was to equip and empower Black women with the needed skills to become their own advocates, pursue their dreams, and do so through mutual aid. Around the same time as this project, Naomi and I both became mothers and over the years we had five children between the two of us. As we became parents and then started growing our families, we often worked together to imagine what intersectional feminist networks could look like in practice. Our projects involved community

organizing for social justice, supporting parents and children, arts education, and open source technology integration in learning spaces. Through our community organizing, we felt that we were imagining a better future for ourselves, our kids, and future generations, where sexism and racism are challenged and erased.

Toward this vision, we decided to incorporate Naomi's soccer workshops into the solar punks work being done in Amsterdam and Vienna, to create an international conversation about how Black women in Pittsburgh are creating a better future for themselves and how allies can support them in this work. About the soccer workshop series, Naomi said:

> It started as a need for me to get active and reclaim my physical strength and stamina. I was also in dire need of sisterhood with other Black mothers who I feel I shared a unique experience with and wanted to play with my friends and other community members that I felt could benefit as well.

According to Naomi, the main purpose of the soccer workshops was for Black women to have fun, examine how their bodies and minds felt while they played, build goals together, and care for each other. Held over the course of several Sundays at a local soccer field in Pittsburgh, dozens of Black mothers and aunties came together under Naomi's coaching and went through a series of exercises before playing a soccer game together. As part of the warm-up routine, Naomi had each woman write their goals in permanent marker on their soccer balls and then take turns kicking their goals into the net. It was a powerful exercise that helped women to identify their goals, work together to make them happen, and celebrate one another along the way.

Figure 7 Erin and Naomi Screen Printing Soccer Jerseys in Summer 2022

As part of the soccer series, Naomi and I created soccer jerseys in vector design software, cut the designs on a computer numerically controlled (CNC) vinyl cutter, and then adhered the vinyl sticker stencils onto screens for screen printing. Together, we screen printed several soccer jerseys for the moms to wear as well as several for the aunties to wear. The idea is that everybody wins because we are all supporting one another.

Figure 8 Soccer Mommies Wearing Their Jerseys

During our monthly conversations with organizers in Amsterdam and Vienna, we talked about pod mapping, an exercise where individuals identify the people in their lives who they can rely on for mutual aid. About the pod mapping exercise, Naomi said:

> I literally heard of pod mapping from the Solar Punk meetings and it had a profound impact on me. It's something we all do in one way or another, but I never thought to formally do it on paper and take account of who/what is my support system and how do I make it count more and stand for others in a more meaningful way.

As part of the soccer series, we challenged ourselves to connect the theme of supporting Black moms and aunties in Pittsburgh to solar punks in Amsterdam and Vienna. Naomi and I were frequently in conversation with one another about how parenting should be a community effort and that the soccer games actually served as an approach to open source parenting, where moms and aunties are invited to hack our social systems. By playing and discovering with one another, they found ways to show up for one another, discuss their dreams, and align their goals.

As part of this ongoing conversation about how allies can support Black women in Pittsburgh, Naomi and I decided that providing childcare during the soccer workshops would be an important part of making sure that the workshops were accessible. For this reason, I worked with another white organizer to provide games, snacks, and activities for the children of the soccer moms during the workshops.

Figure 9 Mommies, Aunties, and Children After the Soccer Game

Providing childcare in any educational setting is an important part of working toward gender and racial equity. This was part of our effort to apply the exercise of pod mapping toward tapping into sources of mutual aid. In doing so, I saw how important it is for allies to show up and help out in whatever way makes sense, whether it is with logistics, communication, or providing food. By reducing the logistical stress of creating events, allies can play an often overlooked but important role in building and sustaining intersectional feminist networks.

Figure 10 Chalk Drawing from One of the Children at the Soccer Series

Naomi's work exemplifies intersectional feminist networks of support in by centering the lived experience of participants, focusing on depth of relationships over scale of partnerships, and anchoring the work in collective survival for Black mothers. Naomi's work also demonstrates an ecosystem approach to advancing equity in education in several ways. First, her work starts with an assessment of local needs and fostering mutual aid among participants, such as childcare and transportation. Second, her work shows what it means to break out of organizational silos and mindsets by taking a creative and hands-on approach to building relationships of trust and support among learners. Third, her work shows what it looks like for a community to reach an agreement about its shared values and goals (and then literally kick those goals one by one into a soccer net!) Finally, her work shows what it means to identify and redistribute resources to isolated individuals, and Black mothers in particular.

Imagining intersectional feminist networks of support is not only possible, it is already happening. Each day, educators, artists, community organizers, researchers, and activists like Naomi are involved in creating alternative places and structures both for subverting existing power dynamics and offering professional development that helps people learn how to center equity in their work. Investing in an ecosystem perspective of learning and development helps us to see that within-an organization is not the only approach we can take to create equitable change. In fact, we have to think beyond individual organizations and programs, which can be particularly disruptive for existing structures.

Throughout this dissertation, I have found that when feminist makerspaces take an ecosystem approach toward creating change, their efforts are more likely to be sustainable and coordinated as part of a larger regional strategy. Similarly, when education networks center feminism and anti-racism in their work, their efforts are more likely to further equity across learning environments. As such, feminist makerspaces and education networks both have the potential to provide an alternative route to either complement or disrupt organizational change and learning. By agreeing on shared values, centering racial justice and gender equity, and working across organizational silos, we can work toward transformational change in education, in our communities, and in ourselves.

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