CRITICAL PARTICIPATORY EXPLORATIONS OF YOUTH STEM PATHWAYS

By

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ABSTRACT

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Using a critical ethnographic participatory research approach and a new analytical method of *critical participatory co-analysis*, I worked with youth research partners to explore their engagement in STEM learning over time and space. We examined how youth navigate STEM learning spaces, how they act to reimagine and recreate the world around them, and how different practices and resources support learners' critical mobilities, enhancing their efforts to construct STEM pathways to their desired futures.

Youth seek desired futures in increasingly complex and multilayered ways with agency and purpose. Institutional structures have consistently demonstrated patterns of working against these efforts, especially for Youth of Color and youth from low-income communities (National Science Foundation, 2019). Learning ecologies are layered with power in complex and dynamic ways that position and constrain youth pathway efforts, increasing the urgency of understanding youth perspectives on how structures can better support their efforts to build their futures with STEM. I sought youth perspectives on practices of their learning mobilities and geographies, with special attention to critical out-of-school mobilities of youth who were seeking STEM-oriented futures. I used a critical justice definition of equity to examine the complexity of youth pathway efforts in systems of power that mediated resource access and influenced their purposes, perceptions, and actions. Questions included: How do youth who engage in informal STEM programs construct pathways across their learning and development spaces towards desired futures in STEM? What do their pathway-making efforts look like and include over space and

time, how are efforts structured/supported, and how do youth, in their own words, understand those efforts?

I partnered with five youth to learn more directly from their perspectives as members of communities historically marginalized in STEM (Youth of Color from low-income communities in Michigan). I had known and worked with youth research partners for years through my teaching practice in an out-of-school (informal) STEM engagement program. We co-generated data (including multimodal portfolios, representations, and narratives), and we conducted critical ethnographic participatory research to better understand the complex components, structures, and directions of their pathways. We then developed an innovative approach for co-analyzing the research data we had co-constructed together, *critical participatory co-analysis*. This helped me to arrive at findings that were built from multiple data points and perspectives, acknowledging the legitimacy of youth expertise over their own lived experiences and pathway contexts.

I found that youth constructed STEM pathways through practices of a) navigating the world as it is, b) working towards the world as it could be, and c) processes of becoming. These practices demonstrated how youth experienced and made sense of their pathway construction efforts within and against the worlds in which they lived as they moved towards their futures. Findings rethink what pathways include, how youth navigate the world towards their desired futures, and how they reconstruct their world in order to reach that future. This advanced a) understandings of learning ecologies and pathways, b) methodologies and methods for learning about pathways, and c) knowledge on equity in informal STEM learning, with implications for researchers and practitioners.

This dissertation is dedicated to my little brother, who was taken before he had a chance to realize his full potential in life and before he could see his dreams become a more tangible reality in the world. Kellin asked important and difficult questions about life and our responsibilities to each other as fellow human beings traveling different pathways together. He was critical of dominant voices in discourse, and he vehemently critiqued people in power who acted hypocritically. He loved animé, funny YouTubers, the Kingdom Hearts video game, and absurdist comedy shows like Tim and Eric Awesome Show Great Job. He called himself a connoisseur of ramen noodles and pumpkin beer. He struggled in social situations and often remained silent around all but a select few, but those who embraced him with loving respect, and were patient enough to get to know him over time and one-on-one, were rewarded with a loyal and clever ally and confidant. His social and neurodevelopmental realities also often positioned him with opportunities to use silence as a tool to sharpen his observations, leading him to notice details others overlooked. He reveled in his own unique brand of surrealist humor that often leveraged this skill for detail. When asked by his music school department to advertise his final exam performance, for example, he posted flyers on campus announcing, "Come to Kellin's Recital Exam," with the letter *i* in recital purposely missing. He beamed with victorious jollity as he shared with me how he had successfully gotten his department secretary's signature of approval on the flyer without her noticing his spelling choice. He was my first and most constant friend. As a young adult, he joined a traveling circus to play in their band, and he took selfies with elephants. His real passion, though, was classical music. He was invested in a long journey towards making it in the hierarchical world of orchestral music. He was a struggling millennial with big dreams that he held close. A composer at heart, Kellin always had a project in the works. He also always had a snarky opinion ready to share about popular music (e.g., Muse copied Queen, Queen copied Beethoven, and everybody copied Bach). One time, he wrote arrangements for a Led Zeppelin cover band's backing orchestra. I got to watch him conduct that orchestra in a sold-out performance, and a concert hall full of aging Zeppelin fans in old concert t-shirts gave him a standing ovation. One of his best friends from music school said that Kellin always pushed him to not give up on his own composing work. He always reached out to help others around him, whether that meant offering advice and assistance to other musicians, interceding as a peacemaker for quarreling friends, or checking in with family. His heart was bigger than mine. He made me want to be better, and he made me want to do better. He was preparing for another round of orchestra auditions this year.

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This study was a labor of love with youth research partners Keke, Amara, Sincere, Jazmyn, and José. They are my kids and my heart. They are already making the world around them brighter and better through their intellect and passion, and I know this will continue in big ways in the future. I hope to make them proud. They make me proud every day.

This research was supported by a UK-US "Science Learning+" partnership grant to explore youth informal science learning pathways. The US sites represented in this study were supported through National Science Foundation grant 1647033, "Science Learning +: Partnering for Equitable STEM Pathways for Underrepresented Youth" (PI Dr. Angela Calabrese Barton, Co-PI Lynn Dierking, Co-PI Carmen Turner). Research involved sustained collaboration with UK partner sites (PI Louise Archer, Co-PI Emily Dawson). Collaborative meetings were invaluable opportunities for me to benefit from a cadre of critically oriented out-of-school STEM learning leaders who made me feel like an equal in the room as they worked to support, challenge, and expand our shared work.

This dissertation could not have existed in anywhere close to this form without Za'Mani and Akeya Roper, Willie Dawson; Karen, Kaila, and Jaila Williams; Emanuel and Valerie Kemp; Mahkai Ealey; Honesty Anderson; Angela Calabrese Barton; Edna Tan; Carmen and Chandler Turner; Micaela Balzer; Betsey Mappilaparampil; James McAbee; Ger and Joseph Yang; ReAnna Roby; Sarah Keenan; Christina Restrepo Nazar; Myungwhan Shin; Kathleen Schenkel; Pablo Lopez; Autumn McDaniel; Stephen Harden; Katie Selway; and countless other people in Michigan who funded, believed in, designed, energized, supported with their talents, or

otherwise made possible the afterschool STEM programming and youth research partnerships that this dissertation discusses. They are creators and supporters of youth dreams and futures.

Rand Spiro, Aman Yadav, Vaughn Watson, and Louise Archer are role models who prove to me that “the academy” can be more than an ivory tower. It can be a meeting place for complex humans to share their humanity with others. It can be a place that welcomes individuals who want to wrestle with difficult questions about life and the people living it. It can be a place I would be proud to join.

Angela Calabrese Barton is not only the reason I survived graduate school; she is also the reason I decided to apply in the first place. The longer I spent teaching at a large metropolitan science and technology center, the more I wrestled internally with nagging questions about what power structures I was upholding, what messages about STEM I was spreading, who my institution was welcoming and who it was ignoring, and what ways of being in STEM different youth from different backgrounds were supported in exploring. I wondered if anybody else cared about those kinds of questions, so I started Google searching with terms like race, gender, out-of-school, science learning, and identity. Dr. Calabrese Barton’s articles came up more than anyone else’s. I ended up cold-emailing her to ask her about her research (and to get some free copies of her articles). It only took reading one article to get me hooked. This is what research could sound, look, and feel like? Our conversation awoke ideas about potentially trying out a different career track so that I could work in partnership with youth and communities to seek new possibilities in informal STEM education together. Then, through Angie, these ideas suddenly began turning into reality. Angie pioneered this field, and she continues to bring up new scholars as apprentices and partners as she works to continue expanding it. She is the mentor who has never given up on me. She continually challenges me, and the world around her, to be more aware, more critical, more thorough, and more fearless. Her radical, imaginative belief in the possible makes impossibilities realities.

Maxwell Johnson is one of this world's truly good people. He works to improve life for those around him just as he works to improve himself. He is constantly seeking to learn more about others, and he pushes his students, friends, and colleagues to approach the world's power structures with a critical justice perspective. He cares about people and truth, and he acts on that care in concrete, impactful ways. Each day, in both his words and his actions, he makes me incredibly proud to publicly claim him as my husband, my partner, and my friend.

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Opening Vignette

I met José in his fourth-grade school year, when he was too young to join but already eagerly interested in the goings-on of the STEM Club room at his Michigan Community Center. He never missed a STEM Club "community event." Even when explicitly forbidden by adults, he would knock loudly on the door until someone answered, at which point he would beg whoever had opened the door to let him in. He would hound his older peers with questions about their ongoing projects, and he would sometimes even bring friends of his with him and ask if they could visit as well. This happened frequently enough that all adult mentors knew him by name and greeted him when they saw him in other areas of the club. We occasionally engaged José as a visiting "special helper" on slow days because of these determined efforts to get into the room and participate in activities.

In his sixth-grade year, when finally an official STEM Club youth with full membership, José hit the ground running—literally. At the fall recruitment/welcome day event for GET City, he ran through the wide-open door of our new makerspace with a triumphant yell. Once inside, he kept running as if taking a victory lap. He jumped and skipped from one station of the room to another, touching as many things as he could. He asked us to recall all the times he "tried to sneak in" before and how many times he had been told "no." He exclaimed to adults his excitement about finally being able to claim his rightful presence in the space, pointing at us with a big grin and teasing, "You can't kick me out anymore!" This was a day of much-awaited glory. José was finally being officially and publicly recognized for what he knew all along: he belonged here.

One day in his seventh-grade year, I asked José if he wanted to do research with me on his "life pathway with STEM." During our first session together for this study, I explained that I thought a lot of other people, both youth and adults, could learn from his experiences and his expertise as a young STEM (science, technology, engineering, and math) learner and enthusiast. I explained that I wanted to work together to help him make a "portfolio" to organize all those experiences and expertise into something concrete that we could then analyze and reflect on together. He excitedly took over my laptop and, unprompted, wrote out an introductory message that would serve as his opening page of such a portfolio. He typed quickly and decisively, crafting a hello that delivered a sense of urgent concern and warning to whomever might come across his portfolio in the future:

> There are different paths to each destination in life. I want to tell you about my paths I take and the paths you and everybody else has to take. You have to choose the right decisions, and the paths to take are not always the paths that you choose. It's not always a straight line. It has twists and turns. But it's worth it if you make your dream come true… Look out for the twists and turns because some might be dangerous! You might have to… risk stuff. [his ellipses in this sentence, for emphasis through a dramatic pause] (José's portfolio, 2017)

Later that school year, in discussing his research on this pathways project, José argued:

> I think it says that I've really come far as a hard worker and I've achieved a lot. I'm good at learning and I know that I can grow even more. I'm going to be an awesome scientist or engineer. (José's portfolio, 2018)

He added that he considers himself a scientist and engineer currently, but in the future, "I'm going to be a more awesome one."

José could see his learning and development with STEM growing over time. He understood how some structures mediating STEM engagement were riskier than others (e.g., he knew that his low math grades in school put him in danger of losing his state college scholarship). He had also gained some knowledge and skills over time that helped him to better navigate such risks (e.g., getting math homework help afterschool). He understood that working towards his "dream" with STEM would require continually pushing against unjust ways that world worked to diminish that work, in his complex positionings as young Biracial boy in the world (e.g., watching racist presidential remarks attacking Latinx people's worth on the news while heating up some dinner for himself, as his Puerto Rican mom worked late night shifts to save for a math tutor).

José was taking deliberate efforts to create pathways to his desired future in and with STEM. He sought out support to twist and turn himself around to fit into the pathways that were not designed for him (e.g., a tutor's support in raising his grades in a math class that was leaving him behind). In some cases, he took action to open up or reimagine pathways that were closed or nonexistent before (e.g., when he created a YouTube channel for educational STEM videos, by and for kids, as an alternative pathway for him and other youth to learn and practice STEM on their own terms). He explained that "stretching towards success" included necessary acts of working on himself as well as working on the pathway structures around him.

This dissertation explores José's pathway, and the pathways through life that other youth are taking, through new original methods and approaches that seek to honor and leverage the complexity of young people's real lives. Youth are fighting against inequitable systems right now, every day, to chart a future for themselves with STEM. Using a critical ethnographic participatory approach to co-generate multilayered youth data, and by creating a new analytical method I call *critical participatory co-analysis* to co-examine that data, I seek a shared understanding through shared investigation of youth lives with and in STEM. We focus on out-of-school STEM pathway-making efforts as sites of possibility, agency, and purposeful commitment to advance learning and development in STEM.

Youth STEM Learning and Development "Pathways"

A pathways lens draws from a learning ecologies perspective to consider how individuals move within, across, and through learning spaces toward possible futures (Bell et al., 2012). Pathways can be facilitated, designed, built, negotiated, shifted, and/or morphed by external structures as well as by individuals themselves (Lyon et al., 2012). Researchers and educational leaders have used a pathway frame to push back against the previously popular but narrowing metaphor of a "STEM pipeline" (e.g., Lyon, Jafri, & St. Louis, 2012; Cannady, Greenwald, & Harris, 2014). A pathways lens for understanding participation in STEM (science, technology, engineering, and math) discipline learning and career preparation can address some two-dimensional constraints of a pipeline metaphor, but researchers must further open up pathways discourse and literature to make room for more complex, critical, and multidimensional explorations and representations. This includes explorations and representations of perspectives and efforts that have been previously overlooked, as well as components of pathways that are not traditionally defined as part of STEM.

Learning and practice are grounded in historical, physical, and contextual location (Bright et al. 2013). But these locations (e.g., the locations populating geographies of informal STEM learning) are dynamic and are always in-shift and/or under construction, comprised of geographical and temporal-spatial spaces of learning that are implicitly structured and mediated by relations of power. The pathways that youth attempt to construct across such geographies must trace across such power relations, a requirement that calls into question what power dynamics (and in what forms) facilitate or constrain movement on pathways. Pathway construction efforts can be understood as "inevitably and everywhere imbued with power and meaning and symbolism" (Massey, 2013, p 3). This means that anything spatial is "an inherently dynamic simultaneity… an ever-shifting social geometry of power and signification" (Massey, 2013, p 3). In this way, Massey (2013) explained and described living as a task that requires movement across and practice within spaces that intersect and/or layer atop each other over time, align together in parallel, or fight against each other "in relations of paradox or antagonism" (Massey, 2013, p 3). Drawing from Crenshaw's (1989) thoughts on the intersectionality of power-mediated and power-encoded identity and practice, it becomes clear that intersectional identity and positioning in matrices of power, oppression, and privilege (Collins 2000) affects all youth mobility and resource access/use within and across space and over time. This means that power is always at work in youth learning and development, in complex ways. For example, José's pathway work involved navigating through school authority structures determining his math grades and academic rank among his peers, while knowing that authority figures' goals for controlling his talk in such learning spaces were counter to his ways of learning math through asking peers questions (and while knowing that out-of-school tutoring called for his single mom to work late hours, requiring him to lose her emotional support and her homework help on school nights).

Pathway construction only ever happens in-the-moment, through learners' efforts to leverage resources and co-construct spaces as they both move within and/or across those spaces, over time. But these efforts are always complicated and changed by interaction with the systems which structure them, including the sociocultural and historical systems of power that create privilege and oppression (e.g., systems of racism, capitalist competition, sexism, and elitism/classism actively working against youth in traditional STEM educational structures). For José, for example, this meant that his pathway movement could not always be as linear as he might have hoped, creating a need to be wary of unseen "twists and turns." But he kept pushing forward through the complicated challenges of navigating inequitable landscapes of STEM learning and practice, maintaining that such difficult pathway work was "worth it if you make your dream come true."

I define the resources youth seek to leverage in this pathway work as both components and builders of STEM pathway power. Resources are pathway components in that they are material, discursive, and symbolic objects found within and movable across learning spaces in power-mediated ways; resources are also builders of power in that they organize both learners and learners' activities (Hand, Penuel, & Gutiérrez, 2012). Resources that determine and/or enhance STEM pathway work are inequitably distributed by systems of power, complicating youth pathway efforts across time and space (Tate, 2001). Resources also complicate youth efforts in power-mediated ways because they attach youth to intersecting racial, ethnic, class, and gender positionings that get taken up differently within "predominant cultural frames" or norms (Hand, Penuel, & Gutiérrez, 2012). Negotiating access to traditionally recognized STEM resources is important, but so is creating or creatively repurposing resources for STEM-oriented use.

I define time as both an external dimensional structure and as a dynamic youth tool of interaction and creation. As a pathway structure, time can act as expanding context or constraining container of learning (Leander, Phillips, & Taylor, 2010). As a pathway tool, youth can use time to make change happen for themselves, such as by calling upon time as evidence of development and committed engagement or by leveraging moments as pockets of opportunity (e.g., Calabrese Barton et al., 2013). Temporal coordinates of life locate youth pathway efforts in experienced reality that is concrete, consequential, and interwoven with systems of power (e.g., a chemistry lab homework deadline can be consequential to a young person's grade point average, a concrete component of inequitable college admission structures). Time is also open to imaginative shifts or redefinitions as youth seek to leverage time as a pathway tool (e.g., when Keke used her investment of doing STEM "in her own time" afterschool and at home as an argument for her worthiness in more formal STEM spaces during school time; when Amara explained that she loved doing science, but not during school hours). As demonstrated by these examples, time is always implicitly interwoven with power as both a resource and structure, in complex ways that youth seek to affect as they conduct pathway work.

I define spaces as comprising both physical locations and virtual or imagined contexts where practice occurs. This is partially informed by a Bourdieuan definition of social contexts as *fields* and by explorations of social spaces in science education research as contexts for relationships of power and capital (Archer et al., 2014). My definition of the term *space* encompasses these ideas but also reaches beyond to refer to physical locations where practices happen and the tangible materiality of resources that support practices—like a makerspace and the furniture and equipment within it (Calabrese Barton, Tan, & Greenberg, 2017).

Together, diverse spaces of practice (both physical and virtual or imagined) create complex and intersecting geographical terrains to be traversed as learners mobilize themselves and their resources (i.e., people, ideas, materials, relationships, connections, etc.) toward pathway construction over time. In this conceptualization of space, power and intersectionality play large roles in determining individual's spatial positions (Leander, Phillips, & Taylor, 2010;

Massey, 2013; Rahm, 2014). How each informal STEM learning location (both virtual or imagined and physical) is constructed in local and global configurations is determined, at least in part, by intersectional space-time-power positionings. Space and place are socially and culturally constructed ideas as much as they are actually physical and digital places (Leander, Phillips, & Taylor, 2010; Massey, 2013). Time, too, can be a socially mediated measure of power and expertise, a tangibly felt process of living, and a crucial function of efforts in scale-making and change-making (e.g., Jurow & Shea, 2015; Calabrese Barton & Tan, 2018b). As Rahm (2014) explained, studies of informal (out-of-school) learning environments have begun to "stretch" researchers' theorizations of space and time (p 397). I intend to contribute to and expand on such research efforts in partnership with youth.

Conducting research on pathways necessitates attending to pathway complexity across dimensions and intersections of space, time, resources, power, and additional components explored in this dissertation. For example, José called upon complex and symbolic cultural ideas about movement and power through virtual space as he explained, "I've really come far as a hard worker," a pathway description drawing on retroactive spatial distancing as a measure to indicate forward advancement. This description implied a gaining of something, of skills and/or power to act. It also called up cultural definitions of "going far" in life, an expression referring to material, financial and/or professional achievement. Further, he called upon temporal movement in the same breath, in that his understanding of spatial distance was an effect of looking back from the present to where he had started his movement. With the additional phrase "I'm going to be," he predicted further changes between present and future him as he continued to follow the pathway he had set for himself. Meanwhile, he cautioned audiences that traversing such dimensions towards a desired future was a "risky" and "dangerous" undertaking, full of unfair and/or surprise obstacles ("twists") and real potential for failure at multiple points. It was also a journey that he did not always control. It sometimes involved forging ahead under his own direction and sometimes following others' directions, as he explained with his disclosure, "the paths to take are not always the paths that you choose." Adding the requirement to "look out" while conducting such forging and/or following work revealed the complicated nature of agency and power within/across the structures of life mediating and framing pathway construction work.

Overview of Dissertation

Youth of Color and youth from low-income communities are active learners, thinkers, creators, and problem-solvers who explore the natural and designed worlds around them, get inspired to develop more and more complex knowledge and skills in both STEM subjects and beyond, and seek pathways to successful futures for themselves and their communities. The educational structures that purport to support such youth pathway efforts, however, have consistently demonstrated patterns of upholding inequity and injustice in STEM learning and practice, especially for Youth of Color and youth from low-income communities (National Science Foundation, 2019). This happens when a class discussion only rewards yes-or-no answers and does not welcome a range of other participation styles. It happens when a school field trip to a science center requires a lot of money for admission and those students who do not submit money are separated from their peers and told to stay behind for a study hall day. It happens when homework projects require excessive parental time and effort for successful completion but give little notice to overtime-working parents. There are countless such examples happening every day, in both small and large, implicit and explicit ways.

Informal or out-of-school STEM learning programs have been discussed in the literature as more joyful and welcoming, less rule-restricted, more open-ended and more personally fulfilling for youth compared to formal, in-school STEM educational structures (e.g., National Research Council, 2015). Out-of-school programs have been shown to positively impact school performance of youth with low socioeconomic status (SES), racial or ethnic minority background, a single-parent family, a mother with low formal education, and emergent bilingual status (Lauer et al., 2006). These programs have been called a lifeline of sorts for youth who are not being served equitably in school, with reports of low-income children benefitting from them at higher rates (e.g., Miller, 2003) and with descriptions of out-of-school STEM programs as opportunities for youth historically underrepresented in STEM to access more equitable forms of STEM engagement (Calabrese Barton, Tan, & Greenberg, 2017).

Researchers have linked informal STEM learning to expanded learning opportunities, higher grades and scores in school STEM subjects, decreased disciplinary and dropout events, and increased positive attitudes towards futures in STEM learning and practice (Lauer et al., 2006). Yet access to and equitable opportunities within informal STEM spaces remain more limited for the students from communities that are marginalized in STEM fields, with White and high-income students still gaining access to after school programming in much higher numbers (Harvard Family Research Project, 2006). Exacerbating this issue, there is not enough research documenting the characteristics of out-of-school programs (Lauer et al., 2006), and even less research documenting the characteristics of these programs that youth directly identify as helpful or supportive for their learning and development efforts. There is also limited research on how youth living in marginalized communities move within and across informal STEM learning spaces and in how different practices and resources within those settings can support learner mobility across settings.

These findings increase the urgency for educational researchers and policymakers to better understand youth perspectives of their out-of-school learning mobilities and geographies—the actions and structures of life-wide learning and development. This dissertation addresses this knowledge gap of the field, with a narrowed focus on the out-of-school learning mobilities and geographies of youth who identified an interest in STEM and sought after out-of-school STEM opportunities. This dissertation also addresses the STEM educational research fields' need to explore how informal STEM learning can become more equitable and transformative for youth who seek STEM pathways for their lives.

Research questions. In this dissertation, I asked the following questions:

- How do youth who engage in informal STEM programs construct pathways across their varied spaces of learning and development towards desired futures in STEM?
- What do their pathway-making efforts look like and include over space and time, how are those efforts structured and/or supported, and how do youth, in their own words, understand those efforts?

To answer these questions, I developed new methods and approaches to collaborate with youth as research partners so that I could learn more directly from them, in their words and from their perspectives. I explored STEM learning and development pathways with youth who I knew were seeking STEM-related futures, youth I had known and worked with for years in an out-of-school (informal) STEM engagement program. The youth research partners are members of communities historically marginalized in STEM, as they are all, like the majority of youth I work with in the afterschool STEM program, Youth of Color from low-income communities in Michigan.

Using critical ethnographic participatory research methods, youth research partners and I worked to explore their participation efforts and experiences in STEM learning over time and space (e.g., across physical learning settings, with different people, etc.). We sought new knowledge together on how aspects and components of STEM learning (e.g., mentors, resources, etc.) structured and/or supported their efforts to construct STEM pathways to their desired futures.

Together, we co-constructed a collection of pathway representational artifacts (including visual representations), and we conducted critical ethnographic participatory research to better understand the complex components, structures, and directions of their pathways. We then developed an innovative approach for co-analyzing the research data we had co-constructed together, which I term *critical participatory co-analysis*. This helped me to arrive at findings that were built from multiple data points and perspectives, acknowledging the legitimacy of youth expertise over their own lived experiences and pathway contexts.

Research outline. In the following chapters, I explore five different youth STEM learning and development pathways. First, Chapter 2 will preface the dissertation with a review the literature on informal STEM learning and development pathways and present an argument for why such pathways should be framed through a critical take on mobilities and geographies of learning and social practice theory lenses.

Chapter 3 will cover my combined methodology of critical ethnographic participatory research and how combining critical ethnography and participatory approaches was important for this work. That chapter will also introduce the five youth partners of this work (José, Jazmyn, Sincere, Amara, and Keke) and describe the particular contexts and methods of the study we completed together. This will include an introduction to our particular types of data co-creation methods and novel artifacts resulting from that co-creation. It will also include an introduction to and description of an original method of data analysis I created for use in this study, *critical participatory co-analysis*. Finally, the chapter will detail the research design process, including the three pilot studies I conducted to inform this dissertation.

Next, Chapter 4 will introduce the descriptive findings of my research with the five youth partners, including five co-written narratives of youth STEM pathways, and five youth participatory portfolio case artifacts. This will follow with an initial discussion of the themes from the data that emerged during an additional round of *critical participatory co-analysis*.

Chapter 5 will cover detailed analytical cross-cutting findings from the data. The new method of *critical participatory co-analysis* involved multiple iterations or rounds of analysis, so each layer of findings to share were produced in partnership with youth. For example, as I worked with youth to co-analyze their youth STEM pathway data, our first layer of findings resulted in co-written narratives and co-created reflections on their portfolios of representational pathway artifacts. Our second layer resulted in the emergent themes that we then organized together in a final round of analysis.

Chapter 6, the final chapter, will include a closing discussion of limitations, implications for supporting youth pathways (with a focus on out-of-school STEM pathways), and specific recommendations for educators, designers, and researchers drawn from the study's findings. Appendices will include full youth portfolio artifacts and interview protocols.

Chapter 2: A Review of the Literature

To inform this exploration of youth STEM learning and development pathways, this chapter presents a review of the literature on equity issues in STEM education both in general and with a focus on informal STEM learning. It also presents overviews of my theoretical frameworks of mobilities and geographies of learning and social practice theory, and my conceptual framework of mobilities of criticality.

In/Equitable STEM Education

STEM education is increasingly crucial for social, cultural, political, and economic participation and voice in industrialized and globalized modern life. From personal and community safety to the environmental protection and public health of a region to national- and global-level decision-making about food sources and fuel, STEM is a central area of knowledge and skills for surviving and thriving as a human among humans in the world. As such, the right to access and explore STEM learning and practice could be defined as a modern human right, and the inequitable structures of power that govern formal STEM education have committed violations this right (e.g., Tate, 2001). For example, the hierarchical structures of schools have resulted in many cases in a one-way stream of students listening to teachers, teachers listening to administrators, and administrators listening to policy-makers and/or financial stakeholders (Milner IV, Cunningham, Delale-O’Connor, & Kestenberg, 2018). Curriculum, too, has been implemented in many cases with marginalization and social exclusion as inherent and unchecked design components (Sleeter, 2015). This happens when textbooks leave out the historical contributions of women and STEM pioneers of Color, and when competition and grade curves depend on some youth becoming “losers” to imbue challenges or tests with risk-reward and/or weed-out components. It also happens when engagement with STEM and its power structures is not unpacked in critical ways that support youth in developing the tools to challenge, expand, or otherwise improve those inequitable structures (e.g., when a teacher shuts down or ignores a question about racial profiling during a lesson on fingerprints, DNA, and forensic science).

Understanding the equity problems that plague formal learning spaces increases the urgency of recognizing learners' active engagement practices outside of traditional spaces of privilege and constraint. Opportunity, achievement and interest gaps remain in STEM for youth from historically marginalized communities, despite decades of school reform. However, I echo Ladson-Billings' (2006) argument that the achievement gap between students of Color and White students, while real, misrepresents the fundamental equity challenge. Rather, I am concerned with addressing the education debt—the outcomes of accumulated historical, sociopolitical, economic, and moral policies and decisions, that is owed to communities of Color who have long been marginalized and inadequately served in education. I understand educational equity within the educational debt perspective that recognizes marginalized community perspectives and expertise as overlooked resources for educational researchers, designers, policymakers, and practitioners (Ladson-Billings, 2006). This recognition informed my conceptualization and operationalization of pathways and the urgency of unveiling overlooked pathway construction efforts by youth. Without considering the ways in which institutional and social structures have inhibited pathways to success, we cannot fully work towards more equitable opportunities to learn, move, and become in STEM. I particularly focus on intersecting forms of inequity that youth must face as they seek their desired futures (Sleeter, 2015; Milver IV, 2013). I expand further on this operationalization of equity in my pathway framework of mobilities and geographies of learning (this chapter) and in my overview of my methodology (next chapter).

Racial injustice is a central design component of STEM structures of engagement, in that science, technology, engineering, and math professional industries and educational fields were built within and are still maintained by historical structures of inequity that keep some youth out by design. This happens through such practices as school tracking to limit access to advanced coursework, an increased pressure on teachers of minority students to teach to the test, and when districts inequitably distribute technological and engineering learning resources across schools (Tate, 2001).

One major way this is seen is through curriculum implementation that is acritical and therefore inherently discriminatory, as its color-blindness and equity-blindness ignores both STEM-related and learning-related injustices while they continue to occur in the real lives of STEM learners (Sleeter, 2015, p 136). As King (2017) explained, "Encouraging students to take advanced science and mathematics courses is not enough to motivate them to pursue careers in STEM; more attention needs to be placed on how students are experiencing these courses" (p 11). Researchers have argued that a multi-level transformation of education is needed, including personal changes in how adults conceptualize the children in their care and professional changes in their everyday interactions with those children (e.g., Ladson-Billings, 2009).

The inequitable materiality of different learning environments along lines of race is another consequential component of this racial injustice in STEM. Opportunity to use high-quality, high-speed physical and digital technologies in learning is an inextricable part of the human right to STEM education (a right, in many cases, limited to White middle-class families) (e.g., Tate 2001). William Tate (2001) argued, for example, that material injustice is as important to address as time for and quality of instruction, because achieving expert recognition in science demands a skilled combination of "theory, craft, and technology" (1019). That argument drew from 1999 National Assessment of Educational Progress data which showed that access to computers, telescopes, compasses, and other physical materials positively affected STEM test scores (Tate, 2001, pp. 1024-1025).

Pushing out or ignoring low-SES learners in general as part of STEM education design (whether unintentional or not) widens the net of inequity even further to comprise a diverse coalition of young people who are not served by STEM education structures. Success in STEM subjects is one viable route towards personal and/or community economic advancement for youth growing up in poverty. It also factors into increased opportunities for informed, meaningful, and empowered democratic participation, a crucial vehicle of social and community advancement. Yet high-quality STEM instruction is inequitably distributed, with higher SES students gaining more opportunities to learn during school (Tate, 2001) and being offered more supplemental opportunities out of school (National Research Council, 2015). That lower-income communities of Color experience the greatest levels of environmental injustice in the US, and often their communities' voices are ignored in science-related decisions affecting them, are further evidence of the impact of persistent inequities in access to STEM (National Research Council, 2010).

Furthermore, youth engagement in STEM on issues that matter to the sustainability of their communities is absent from recent STEM education reform initiatives (National Research Council, 2013). Youth continue to invest their time and energy in these efforts despite continued contentious disconnects between formal STEM educational structures and that out-of-school investment (e.g., Bricker & Bell, 2014; Gonsalves, Rahm, & Carvalho, 2013). Finally, the science education research field has limited methods to make sense of how youth efforts matter in the purposes and goals of science and engineering education.

In working with youth to explore and represent STEM pathways and how youth sought to construct them, I worked to address these abovementioned tensions and debts. I am especially committed to the potential consequences that conducting this work could produce for reimagining and redesigning STEM educational landscapes, guided and directed by the perspectives and decisions of youth from marginalized communities. As youth from a diversity of backgrounds, economic levels, races, religions, identities, and orientations seek to create bright futures with and in STEM learning and practice, they have a right to access and explore a wide diversity of opportunities with STEM across those landscapes. They also have a right to participate fully in the research discourse around what opportunities must change and how, across young people's educational landscapes.

Informal STEM learning. The importance of informal (out-of-school) STEM learning environments in young people's lives has been well-documented in the literature. Informal learning contexts offer a multitude of opportunities and resources not traditionally available within school walls, including opportunities to participate in legitimate scientific practices and ways of being that go beyond traditional curricular structures and constraints (e.g., Calabrese Barton & Tan, 2018b). For many youth in STEM from marginalized communities (youth from lower-income backgrounds and Youth of Color) informal learning environments can serve as an academic lifeline. For example, a meta-analysis of the impacts of out-of-school time programs suggest that such programs increase attitudes towards schooling and educational aspirations, improve grades and test scores, and decrease disciplinary action and drop-out rates significantly (Lauer et al., 2006). These programs and environments outside of school hold a special importance in providing access and opportunity, especially for youth attending under-resourced schools (Bell, Lewenstein, Shouse, & Feder, 2009).

Still, inclusion and participation in informal STEM is patterned hierarchically (Dawson, 2014). Equity could be called the most important challenge facing informal STEM education. From access and opportunity to tools and scaffolds for culturally sustaining and justice-oriented experiences, the equity-related challenges in informal STEM are complex and varied. The wide range of informal STEM programs and practices that reach different audiences (Stocklmayer, et al 2010) are often accessible, connected or empowering for only some participants, and especially along racial/ethnic, immigrant status, language, gender, and geographical lines. It is limited in many cases to white and high-SES youth and their families (e.g., OECD, 2012; National Research Council, 2012).

Even when youth gain access to informal STEM programming, they can often experience exclusionary patterns of practice similar to those found in formal environments (e.g., implicit bias and deficit discourse). They can also find informal curricula that do not leverage their lived experience as valued learning resources. For example, when Amara dropped out of her Michigan Community Center's free robotics program, she explained that its lesson structures "felt just like school" with boring tasks that only required her to follow step-by-step instructions and did not care about her ideas or perspectives into the robot building and programming processes. When discussing this later in pathway meetings, we discovered that several of Amara's peers, including Jazmyn, had all felt the same frustrations before also quitting that program, even though it was their only free access to robotics equipment and learning (and they all still thought robots were cool).

All of this limits the voice and impact of Youth of Color and youth from low-income communities in STEM education and the world more broadly. In alignment with a youth-asset-oriented, education debt perspective, the responsibility for changing this pattern must fall on the infrastructures of informal STEM education, not on those who have been traditionally overlooked in the design of such infrastructures (e.g. see Dawson's (2014) equity framework for informal science education).

Critically transforming the cultural structures of informal STEM learning has become an important task for educational researchers (King, 2017; DiGiacomo & Gutiérrez, 2016; Barton & Tan, 2018). Centering youth as valued thought leaders and action-takers (Greenberg & Calabrese Barton, 2017; Birmingham et al., 2017; Vakil, 2014), drawing from community ways of knowing (Barajas-López & Bang, 2018; Barton & Tan, 2018), and working towards social justice in concrete ways with STEM (Taylor & Hall, 2013; Calabrese Barton, Tan, & Greenberg, 2017) have all shown promise in reimagining what role informal learning programs can serve in youth STEM education.

Informal STEM education will never be enough on its own to reverse the accumulated educational debt in the U.S., but it is an important piece of the puzzle when considering the small percentage of time (about 18 percent) youth spend in, versus out, of school (National Research Council, 2009). Bolstering equitable access to, and equitable opportunities within, informal STEM education is crucial to supporting a greater diversity of youth in learning and practicing STEM. Supporting young people's critical mobilities as they move across and seek to connect different STEM learning spaces. More frameworks and tools are needed to explore these challenges and to support needed changes in practice (Feinstein, 2017; Philip & Azevedo, 2017). This study seeks to address that need.

Learning environments and connections across them. Youth geographies of learning include a "wide range of environments" are important for supporting, and opening up opportunities for, young people's STEM learning (Tal & Dierking, 2014, p 251). This focus on a range of environments could be thought of as the “life-wide” component of the National Research Council’s (2009) “lifelong, life-wide, and life-deep” framework for looking at informal STEM learning (p 28). Life-wide learning refers to how “people routinely circulate across a range of social settings and activities,” which requires them to learn not only STEM content, but also “how to navigate the different underlying assumptions and goals associated with education and development across the settings and pursuits they encounter” (National Research Council, 2009, 28).

Because students are complete people whose learning lives don't end when the school day ends, in-school instruction and facilitation of learning is situated within a broader context of students’ lives. Youth in grades 1 through 12 spend only about 18.5 percent of their “16 waking hours” in “formal learning environments” (i.e., school)—meaning they spend more active learning hours outside of school than in school (National Research Council, 2009, p 29). As described above (in “Informal STEM Learning”), meeting these additional active learning hours with supportive educational engagement opportunities that welcome and specifically design for Youth of Color and youth from low-income communities can help to even the educational playing field.

Spaces of STEM learning outside of school occur across a broadly diversity of overlapping geographies. The wide range of physical spaces for informal STEM learning can include unplanned everyday contexts (e.g., conversations and play at home with family, backyard explorations, etc.), local organizations/programs/clubs outside of school (e.g., community-based programs and afterschool clubs), designed places/institutions (e.g., science museums and centers, zoos, aquariums, etc.), and media (e.g., STEM television and radio shows, magazines, websites, mobile apps, etc.) (Tal & Dierking, 2014). If these spaces and contexts are recognized and leveraged by important gate-keeping adults (e.g., science teachers), they can act as mutually complementary geographies for expanding life-wide learning and development. This would require more than simply increased access—it would require deliberate moves to facilitate and support learning and development for diverse youth by helping them take advantage of informal STEM learning spaces and contexts as well as helping them move between such geographies (Tal & Dierking, 2014; Calabrese Barton & Tan, 2018b).

While efforts continue to explore and affect complex structures of informal STEM programming, educational researchers are also working to explore and enhance the connections between those programs and spaces. Youth move within and across a wide variety of spaces, leveraging their STEM learning and development resources to build pathways across space and over time. When formal and informal spaces work together in critical dialogue or partnership, for example, teachers can gain opportunities to recognize and leverage their students' informal learning as classroom resources (e.g., Calabrese Barton et al., 2013, Calabrese Barton & Tan, 2009).

Pathway construction is the effort by youth to connect such spaces across their lives and over time as they seek their desired futures. This shares similarities with the connected learning literature (Ito et al., 2013), a concept which seeks to acknowledge that learners can benefit when resources, youth interests, and academic institutions are socially connected. Connected learning asserts that "effective learning is lifelong and integrated into the real world of work, civic engagement, and social participation" (Ito et al., 2013, p 14). This approach focuses on new media (e.g., Minecraft, websites, etc.) as tools to support the design of "educational alternatives that expand and diversify… pathways available" (p 14). It seeks "entryways" (p 46) to connect "social, academic, and interest-driven learning" (Ito et al., 2013, p 47).

Researchers have sought to support learning in more connected or life-wide ways; for instance, by looking at how teachers can facilitate successful interactions between formal and "realistic contexts" for youth during boundary events (Feinstein, Allen, & Jenkins, 2013, p 316). This could include place-based and project-based teaching, institutional partnerships, and the use of citizen science websites and science games as "productive ways to integrate informal experiences… into schools and classrooms" (Feinstein, Allen, & Jenkins, 2013, p 316). In another example, Kisiel (2014) positioned teachers as "brokers" of such events who could facilitate bridges across learning contexts (p 360).

Looking at successful interactions during individual events is an important effort in the field, but one that will never be sufficient for understanding learner mobility across multiple, diverse spaces. Tal and Dierking (2014) explained learning as "cumulative, emerging over time" (p 252), "across and between multiple social worlds" and across "multiple domains and settings" (p 254). Learner movements across learning settings interact in dynamic ways, influencing young peoples' constructions of meaning in STEM as well as their attitudes and behaviors in STEM subjects—this positions STEM learning is "an organic, dynamic, never-ending, and quite holistic phenomenon of constructing personal meaning." (Tal & Dierking, 2014, p 252).

I argue that expanding support for more connected or life-wide STEM learning and development would need to include recognizing diverse youth as worthy thinkers and leaders who deserve a say in how their learning and engagement is organized, recognized, and defined. Examining and challenging who gets to define different environments as educational spaces, who gets to define learning and engagement as STEM-oriented, and who gets to define particular practices as important or supportive for STEM learning and development are important inquiries to address in this effort. Young people have shown that they are capable of defining their world and of defining what that world could become in the future (e.g., Birmingham & Calabrese Barton, 2013).

Expanding this support would also require critically unpacking youth interest-driven learning with a more justice-oriented acknowledgment that youth care about purposes of their STEM learning in ways that go deeper than interest. This youth in this study, for example, sought STEM pathways for themselves that allowed them to address systemic injustices in their lives, using STEM learning and practice as tools for working towards system-wide change. This went beyond interests in games and websites and beyond individual meaning-making practices. They engaged in STEM for others in their communities as well as themselves, seeking a shared experience of social justice and brighter futures in and through partnership. Addressing and transforming systemic injustices as a part community-engaged and critically oriented STEM pathways helped youth to open up more multidimensional possibilities for the future. Supporting such efforts can begin through youth-adult partnership work that seeks more shared understandings of life and its diversity of contexts.

Limits of pathways. Supporting youth in following their dreams with STEM across their life spaces does not necessitate a pathways lens. One could likewise research youth mobilities of criticality, youth agency in STEM decision-making, and structures of power that frame and mediate youth futuring actions throughout life without mentioning pathways. Looking at these efforts as STEM pathway construction, however, responds to particular ongoing discourses in educational research and policy that frame youth learning and development efforts. These include outdated but still-in-use discourse on youth learning efforts in STEM as part of a "STEM pipeline" (e.g., Cannady, Greenwald, & Harris, 2014). They also include limited but still useful discourse on "STEM pathways" as linear learning and development paths chosen and followed (e.g., Lyon, Jafri, & St. Louis, 2012). At the same time, this dissertation reaches beyond such discourse to acknowledge and explore youth co-construction of pathways and youth efforts to navigate or challenge power structures mediating their construction efforts.

Using a pathways lens is not enough on its own, but it is a helpful tool. When combined with critical social practice theory and operationalized through a mobilities of criticality approach, it can open up new ways to see youth movement and action. It can also help researchers explore youth learning and development as complex and multidimensional across dynamic and co-constructed layers of space and time. In addition to this, it facilitates a shared dialogue with youth through borrowing some vocabulary from general spatial, geographical, and sociocultural knowledge (e.g., youth and adults share general schemas about maps, timelines, forked paths, lane changes, horizontal versus vertical movement, how different spaces convey different messages to visitors moving through them, how the same space can convey different messages and support or allow different types of movement depending on the visitor, etc.). Finally, a mobilities of criticality approach to exploring youth STEM pathways opens up and facilitates a deeper exploration of how power works across all of these dimensions.

Framing Pathways through Mobilities and Geographies of Learning

Why take a mobilities lens. I draw from mobilities and geographies of learning theories (e.g., Leander, Phillips & Taylor, 2010; Calabrese Barton, Tan, & Greenberg, 2017) as well as social practice theory (e.g., Holland et al., 2009) for understanding learner movement and what that movement produces across space and time. A mobilities and geographies of learning lens is grounded in sociocultural approaches to understanding and exploring learning and development (Leander, Phillips & Taylor, 2010). It uses an expansive view of those actions, which helps researchers to look across space and over time (Engeström & Sannino, 2010).

Mobilities links learning to "space and place," by examining youth practices across geographies of learning (Leander, Phillips & Taylor, 2010, p 329). Rather than the term movement, which refers to embodied action, mobility comprises both physical and virtual (imagined, social, digital, etc.) actions of youth through engagement within and across geographies of learning (Leander, Phillips & Taylor, 2010, p 339). Geographies of learning are dimensions of life practice that overlap and laminate over time to form "multiple coeval space-times" as contexts of youth participation in learning (Leander, Phillips & Taylor, 2010, p 332). An afterschool STEM program, for example, can simultaneously occur as a learning space, a friendship-development period, a hierarchical culture-reproduction space, and a moment of opportunity for developing ideas about possible futures. Physical places, then, can also be thought of as "negotiated space, as locations in a nexus of relations" and always dynamically interacting with learners who move through them (Leander, Phillips & Taylor, 2010, p 371).

This concept of mobility in and across space-time-power positionings can also be taken as speaking to and complicating previous research on learning as moving sets of knowledge and skills across diverse contexts. In this way, mobility pushes educational researchers to rethink such ideas as expertise development and transfer. For example, mobilization of strategies and learner recognition of overlaps across diverse life contexts are skills that share similarities with progressive problem solving in knowledge building and expertise research (Bereiter & Scardamalia, 1993). This is because as youth recognize their spaces as connected and multilayered, they can mobilize their pathway actions in more connected and complex ways. Moving towards more complex and layered challenges is a practice that asks learners to think and act beyond internalizing and repeating routines, a mark of built and exhibited expertise (Bereiter & Scardamalia, 1993). It asks learners to take more risks with their learning, in more practical and consequential ways. This is what youth do when they seek futures that require of them continually new and challenging pathway work. Youth in this study seek futures that demand expertise development from them, both in STEM content and in life context.

Mobility also supports youth in pathway development in a way that can expands on previous ideas of learners constructing their own "trajector[ies] toward expertise" in transfer research (Bransford & Schwartz, 1999, p 68). The long tradition of transfer research in education seeks to understand the circumstances that can best support learners in taking their learning into new situations in life, a feature that occurs as youth construct learning and development pathways towards their desired futures. Different from the sequestered problem-solving area of transfer research that reaches back to Thorndike, a more recent focus on preparation for future learning concerns youth developing the tools to encounter the unknown in future challenges (Bransford & Schwartz, 1999). Approaching an unknown future involves entering and productively engaging with new spaces of practice and interaction. As youth mobilize their learning and development resources across space and time, they take advantage of different opportunities to leverage those resources in different ways; this can support learner ability to perceive new situations with a critical eye (e.g., Bransford & Schwartz, 1999, p 79). This process can both illuminate and expand possibilities for learners moving forward.

Importantly, mobility research underlines the consequential impacts of youth agency to mobilize their learning and their developing learner identities, as well as structures of power that mediate or constrain such agency in complicated and problematic ways (e.g., Castro, Lalonde, & Pariser, 2016; Cuzzocrea & Mandich, 2016; Spyrou & Christou, 2015). Youth seek to build expertise by transferring components of their lived experiences over space and time. They put effort into growing as people and developing pathways towards futures they desire. Exploring the ways in which those efforts shape, and are shaped by, the world around them can enhance understandings of how pathways get constructed by youth and how adults can support that construction.

Locating learning. If learning can be defined as mobility (Leander, Phillips & Taylor, 2010, p 359), then documentation of youth mobilities across space and time is documentation of learning. This lens also draws from sociocultural perspectives on learning as increased participation within communities of practice but seeks to examine the situated nature of learning by unpacking and complicating the idea of spatial experience over time (Leander, Phillips & Taylor, 2010, p 334). Looking at the mutual cocreation of spaces and people who move within and across them opens researchers up to more multidimensional views of learning, learners, and the multilayered contexts in which they learn. Layering temporal dynamism on top of this complicates ideas of learning contexts further. This was demonstrated, for example, by a young person who leveraged her lived experiences planting potatoes at home as a learning resource in school, intersecting those events with stories about her family's place-based history towards a more richly detailed understanding about botany and a plant leadership role in her classroom (Calabrese Barton, Tan, & Rivet, 2008, p 89). This still, however, does not address criticality, leading to a need for newer approaches to understanding how people interact with the world around them as they co-create that world and themselves in critical ways over time.

How it is undergirded by social practice theory. I combine these ideas with a social practice lens grounded in critical sociocultural approaches for understanding learning as identity development through engagement in practices within and across communities of importance (Holland et al., 1998). Social practice theory is helpful for interrogating actions within social, cultural, political, and historical contexts, and for acknowledging those actions and contexts as important for supporting identity development efforts of learners engaged in the world around them (Holland et al., 1998).

I understand pathway construction efforts as efforts to conduct identity work towards possible futures as well as efforts to learn new knowledge and practices that propel individuals towards such futures. Pathway construction occurs across activity scales simultaneously and over time, in real and imagined places of STEM (e.g., in a physical classroom and in the various community meeting spaces layered on top of that classroom) (Jurow and Shea, 2015). As youth move in time and space, they are exposed to, positioned by, and react to a range of people and institutional and cultural forces (Holland et al., 2001). Local and sociohistorical contexts intersect in dynamic ways across learning spaces, which means that pathway constructors must negotiate between personal and sociohistorical narratives regarding what normative STEM pathways look like (Gutiérrez, 2012).

Combining a mobilities and geographies of learning framework with social practice theory helps me view STEM pathway construction efforts as mobilizations across geographies to produce change. Equitable learning geographies could include opportunities, resources, relationships, locations (formal and informal, novel and everyday), connections (e.g., social, resource, and knowledge connections), and commitments that support learning and development for youth. These geographies could also include both the physical, material spaces that comprise traditionally conceived “learning environments” as well as the “imagined geographies of place, trajectory, and network” (Leander, Phillips, & Taylor, 2010, pp. 330-331). Science learning, for example, does not take place in vacuum-sealed silos. Young people observe, explore, and question the natural world around them every day. They leverage resources such as knowledge, practices, ideas, and relationships, and they mobilize these resources within and across spaces to support the construction of learning and development pathways.

By exploring multiple scales of such action through these lenses, I can challenge traditional assumptions about practice within communities. For example, this work can illuminate real and imagined boundaries of STEM learning and practice, and the ways in which those boundaries change over time and across scale (Leander, Phillips & Taylor, 2010). What locally defines and bounds pathway-relevant values like skills, formality, and expertise can change as learners work to move and position themselves and others in critical relation. These shifts can help define who can do STEM, and where and how learning and doing matters, adding to the urgency to better understand what supports or hinders youths' efforts to achieve such changes for pathway construction success.

Making it critical. A Mobilities of Criticality lens (e.g., Calabrese Barton & Tan, 2016; Calabrese Barton, Tan, & Greenberg, 2017) takes these ideas and adds the additional dimension of power into the matrix under examination. Learning across space and time requires a critical engagement with the power-mediated world and the people within it (Freire, 2007). Mobilities of Criticality seeks to reveal this critical engagement as mobilities along and through pathways that lead to being and becoming in a community of practice that continues to change (Calabrese Barton & Tan, 2018a, p 20). It explores how such mobilities require negotiations within and across boundaries of learning spaces, youth strategies for successful navigation across dangers inherent to inequitable spaces, and actions for challenging forms of power that structure learning spaces.

Mobilities of criticality takes a Freirian approach to exploring issues of equity in youth learning and development, in that it focuses in on how learners must address "the word and the world" in order to participate in practices (Freire 1970, as cited in Calabrese Barton & Tan, 2018a, pp. 20-21). This approach is grounded in critical justice views of learning as occurring within and informed by systemic injustices that "give texture to the local practices" of learning, and in sociocultural views of learning as dynamic social practice in interaction with resources and relationships (Calabrese Barton & Tan, 2018a, p 21). This approach asks "*Who* is mentoring or learning, *what* is taught and made and *why*, and *how*… success is defined and measured" (Calabrese Barton & Tan, 2018a, p 21).

Mobilities of criticality understands critical justice as going beyond distributive and relational views of equity. It seeks to challenge "participation boundaries and knowledge hierarchies" within communities of practice (Calabrese Barton & Tan, 2018a, p 21) by paying attention to how youth move through "intersectional geometries of power" that are connected to historicized injustices as they work to enact their rightful presence within their learning spaces (p 29).

This conceptualization of equity uses a multidimensional framing to understand many different and intersecting forms of injustice as simultaneously acting on youth efforts across space and time. As Milner IV et al. (2018) explained, "homogenous communities do not exist" (p 12), and equity issues must be explored across race, gender, socioeconomic status, sexual orientation, and other social categories of life and practice. This is informed by Sleeter's (2015) "race and class visible equity in access" acknowledging intersections of racism and classism in the classroom, as well as Milver IV's (2013) argument for pedagogy that equips youth to identify and challenge intersecting forms of inequity across "the many isms and phobias that they encounter" in their lives (p 40).

As I lean towards a working definition of *equity* that acknowledges multiple and intersecting forms of power and oppression, I also lean towards a working definition of *critical* that fits with this acknowledgement of complexity in structures of injustice. I start with an understanding drawn from intersectionality literature that *critical* refers to "criticizing, rejecting, and/or trying to fix the social problems that emerge in situations of social injustice" (Collins & Bilge, 2016, Section 2). But I layer on top of this an understanding that any such endeavor will require multiple perspectives and intersecting layers of analysis to uncover what dominant discourse actively seeks to bury.

I acknowledge truth as a shared reality, so research should be a shared endeavor that welcomes the critical reflection of actors across multiple power positionings (Freire, 2007, p 68). I seek this truth through transgressive research that embraces a feminist, postmodern paralogy distrustful of dominant metanarratives (Lather, 1993), a bridging of "ethics and epistemology together in self-conscious partiality" that "leaves space for others to enter, for the joining of partial voices" (p 683). I also acknowledge reality in the world as a shared object to be studied and transformed (Freire, 2007, p 37), which to me means that dominant interpretive frames require continual, critical analytic disruption.

This concept of criticality seeks to disrupt repertoires of reproduction in research through questioning postpositivist assumptions of neutrality by presenting them as problems to be examined. Such disruption seeks a liberatory turn through praxis that combines research and practice in solidarity towards justice-oriented change by engaging in "critical thinking," as a tool for re-humanization through a re-seeing of the world and the power-mediated discourse structuring it (Freire, 2007, p 81). Such disruption also follows traditions in social justice activism to question dominant power-holder statements, actions, and interpretations that are presented as neutral truth, including a history of protest arguments advocating disruption such as "Silence is violence" (Black Lives Matter, 2017), and "Neutrality helps the oppressor" (Wiesel, 1986). Finally, such disruption requires an understanding of how positionings and actions are grounded in and always mediated by historical and social contexts of injustice (e.g., Collins & Bilge, 2016). This understanding informs my dissertation in several ways, including increased critical attunement to my own White researcher positionings' consequences for how I see and interpret youth data and the related urgency of inviting into that dissertation more voices and perspectives, including those of youth directly.

Mobilities of criticality and pathway work. Understanding critical youth mobilities across geographies of STEM learning is an important task for educators and educational researchers who seek to support such movement and the opportunities it affords for increasing equitable access to STEM.

Using a mobilities of criticality lens, I foregrounded purposeful movement through geographies of learning as constituting pathway construction. But that construction of pathways is always an in-the-moment phenomenon. It is also realized through participation in practices against complex backdrops of sociocultural and historical movement and structures that seek to constrain such practices (e.g., Rahm, 2012; Archer et al., 2012). Such movement can be realized both horizontally and vertically (Engeström & Sannino, 2010).

Many multidimensional, layered contexts set the stage for mobility efforts that support youth STEM learning pathways across settings and over time. This does not merely require a sociocultural lens for seeing context—it requires fundamentally new ways of understanding both space and time as well as understanding student movement and mobility across space and time. Recognizing and attending to students' mobilities and geographies of learning can help to "push open the boundaries of the enclosed classroom as a dominant discourse and historically sedimented geography" (Leander, Phillips, & Taylor, 2010, pp. 330-331).

Furthermore, a critical mobilities lens allows me to explore how movement of learners and their resources within and across space also constitutes a continual co-construction of space (Jurow & Shea, 2015) as well as learner development within space (Gutiérrez, 2012). This increases the urgency to recognize learner agency within complex and continual pathway construction work.

Considering Why Movement Matters with Pathways

Agentic and purposeful movement. Within this backdrop of complexity, inequitably power-structured relationships and interactions affect how each learning space across educational landscapes is configured in and through practice. Power differentials, however, do not necessarily negate co-construction of space. On the contrary, youth can serve as important erectors or destructors of space as they navigate and negotiate across both thin or porous spaces (spaces with room for change and shift) and thick or rigid spaces (spaces institutionally fortified against change and shift). For example, the afterschool STEM program in which I taught exists in part because adults and youth designed, lobbied for, and won funds to support the construction and furnishing of a physical makerspace room. That program also exists in our makerspace room because youth enter it to participate in and co-construct its practices as much as it exists because I enter it to facilitate and co-construct those practices. Ehret and Hollett (2013) explained this through the idea that places are "constantly remade by bodies being in them" (p 112). In this definition of physical space, the construction of space as tangible and realized is indeed a process that implicates persons, including youth, as agentic co-creators of both space and action within/across it.

In this research endeavour, I seek to explore the processes, relationships, and actions by youth (and by others in their lives) that configure each space and place across learning geographies. I also seek to unveil and understand how youth navigate and negotiate across these spaces and places through mobilizations (e.g., mobilizations of their bodies, ideas, resources, relationships, identities, knowledge, practices, etc.). Studying and representing such mobility and the pathway construction that it can lead to across space and time necessitates looking for, coding, analysing, and representing ideas about movement, space, and time as well as agency, identity, sociocultural interaction, resources, power, and purpose.

Individuals move agentically in the world to construct personally meaningful and purposeful life pathways. I use the term agency to refer to an individual's potential for directing their own action in their life through engagement with the world in a variety of ways dependent on context (Varelas, Tucker-Raymond, & Richards, 2015). It is a type of power, specific to the ability to act. For example, José created a YouTube channel to become a more active agent of change in the world, as someone who recognized and used his agency to do something concrete. This meant that he recognized his power to create change by influencing already powerful youth's choices of learning spaces.

Everybody has agency to act in their lives. But those positioned with more power within hierarchical and inequitable systems of privilege and oppression have access to a greater number of spaces, times, and pathways for enacting such agency. They also have a greater number and diversity of resources to support such efforts, and a greater variety of platforms for voicing and gaining recognition for that agency. Furthermore, power-holders tend to recognize the agency of other power-holders more than they recognize the agency of those positioned with less power.

Youth actively participate in the co-creation of their own, unique learning and development pathways within and across inequitable structures of power that frame and mediate such efforts. By exploring young people's agentic efforts to construct pathways in STEM, we can make clearer the mechanisms by which STEM pathways get shaped and directed (both by them and by powerful others in their world). We can also gain insight into where, when, and how we can support youth in their STEM pathway efforts.

Types of movement. Educational researchers have developed some useful understandings of *where* youth move as they learn and develop. We know that youth move both within and across geographies of learning to access and to co-construct different learning spaces. People actively seek out "ways to connect and mobilize themselves *across* social and cultural practices" (Akkerman & Bakker, 2011, p 132). Thus, expertise development "*in* a particular bounded domain" also involves movement across domain boundaries (Akkerman & Bakker, 2011, pp. 134-135). Mobility facilitates the multiplicity of paths required for equitable access to STEM learning. Just as there are multiple spaces to traverse, there is also "more than one pathway" into STEM (Costa, 1995, pp. 315-317).

Space-crossing mobility is not always equally easy for every young person, and the difficulty depends on context that is often affected and complicated by issues of race, gender, SES, religion, nationality, language, sexual orientation, and other factors that problematize a simplistic view of boundary crossing work. Youth inhabit several different spaces every day, including imagined spaces of family, school, self, and peers. Challenges can appear in attempts to move across such spaces—e.g., as youth may perceive some boundaries as "rigid and impenetrable" (Phelan, Davidson, & Cao, 1991, p 240). Transitions between imagined locations must be supported and assisted with appropriate helpers and tools. Thus, Akkerman and Bakker

(2011) charge educational practitioners with the responsibility to “create possibilities for participation and collaboration across a diversity of sites, both within and across institutions” (pp. 132-133). Likewise, studies of youth mobility must recognize both privileged and more “marginalized spaces of social organization” (Akkerman & Bakker, 2011, p 153).

Conversely to *where* youth move, the field of educational research still lacks robust understandings of *how* youth move as they learn and develop. More nuanced and complex approaches for exploring youth mobility could push this effort forward. For example, innovative methodologies and methods I hope to leverage in this project can help to inform future research on how learners use and mobilize resources within and across learning geographies of importance in STEM.

Recognizing mobilities. As children grow, they see the world around them and develop a desire to explore it. These explorations act as learning opportunities that can get taken up and expanded by helpful others (e.g., siblings, parents, educators, etc.). By the time youth first enter school, they are bringing with them a complex history of lessons already learned and scientific phenomena already explored. This complex out-of-school learning history continues to deepen over time, whether or not it is taken up in formal spaces.

Youth move resources across space and time in order to be and become through learning and practice in life. In this study, five young people moved STEM content knowledge and skills to accomplish personally meaningful actions for themselves and for others they cared about. They also moved themselves and their lived experiences in the world and with others to challenge and transform what science, technology, engineering, and math could be and what it could produce. With José’s YouTube channel, for example, he took up his online experiences of watching videos as a resource in his afterschool club with peers in real life. His critical mobility practices helped him negotiate across online, home, school, afterschool spaces and helped him navigate how he could reach out to his peers and share access to STEM knowledge and practice unavailable to him and his friends at school.

Paying attention to how youth take up and use resources to accomplish change in their world necessitates working to understand how youth recognize and define resources around them. It also necessitates acknowledging and exploring the ways in which youth move within and across different spaces in their lives to access various resources. Finally, it requires looking at how such mobilizations occur within complex sociocultural and historical structures that inequitably constrain or shift such efforts.

Looking into all of this is helpful for research as well as practice, including efforts to support youth in accomplishing such mobilities. We know that when out-of-school learning histories and geographies (and their related cultural repertoires of practice and funds of knowledge) are recognized and legitimized by important adults, truly transformative learning and development can occur for youth. For example, when Bricker and Bell (2014) followed one student from 4th to 6th grade using a cultural learning pathways framework to see multidimensional aspects of culturally relevant learning experiences, they learned about how that student's mother positioned science as an elevated and respected domain of practice at home, and positioned her daughter as a scientist. Calabrese Barton et al. (2013) explained that these moments of positionings could be followed to see how identity develops over time through negotiations of context and resources, both within and against expectations of others.

Importantly, the adults who gate-keep spaces of complex, personal, life-wide STEM learning (and movements between such contexts) have the power to support youth in taking up and moving with the learning and development resources found in those spaces. Creating such linkages (e.g., linkages from home practices to other settings) can deepen and further youth interests and expertise development (Bricker and Bell, 2014, p 267), thus expanding learners' opportunities for the future. For example, when teachers seek more complete understandings of their students' learning lives (and the life-wide experiences and geographies the students traverse outside of school time and space), they can better recognize, understand, and leverage student mobility across learning geographies for greater learning and development.

Chapter 3: Exploring STEM Pathways *with* Youth

This is not just some White person's Black Lives Matter story.

It's our story we're writing together. (Amara, 2018)

Critical Youth Participatory Research

New methodological approaches are needed to tackle persistent inequalities in science education experienced predominantly by youth from historically marginalized communities (e.g., Youth of Color and from lower income backgrounds). While youth participatory action research [YPAR, one of many forms of youth participatory methodologies] has been established within the field of educational research more broadly, youth participatory research methodologies are both underutilized and undertheorized in science education research.

Researchers are working to critically explore, interrogate, and expand what we know about youth participatory research practices in science education research and what we need to know in order to advance its role in the field. I seek to advance these efforts through several avenues of work. First, I hope to challenge current traditional frameworks and assumptions for research in STEM education that fail to attend to persistent injustices connected to intersectional power structures of race, class, and gender, through a critical dialogue on youth participation and power in science education research. Second, I hope to reimagine impacts and outcomes of STEM education research across settings, especially along lines of educational equity for marginalized and minoritized youth. Third, I hope to demonstrate same tangible ways in which critical youth participatory research can advance STEM education research. Finally, through this work, I hope to learn more about how ethical and equity-oriented commitments play out in this work and what they can look like. In this way, I hope to provide some examples of potential best practices for conducting this type of work, as well as uncovering specific ways in which this work is still vulnerable to reproducing the systems of power and injustice that it is designed to help dismantle.

New methodological approaches that centralize youth perspectives and challenge problems faced by youth are needed to help tackle these persistent inequalities. More deliberate and multilevel embraces of youth participatory methodologies and practices across different types of educational settings can serve this role. However, critical youth participatory methodologies, while an accepted set of approaches in educational research for over two decades, has had limited impact in STEM educational research. Critical youth participatory research offers STEM education researchers important tools for examining and improving the contexts in which students learn and develop in STEM by inviting diverse perspectives to enhance the practices and products of STEM education research in youth centered ways. It also pushes STEM education researchers to acknowledge and address systems of power that traditionally mediate how diverse perspectives are taken up and legitimized, supporting more transparent and equitable research practices and results for youth.

Broadly speaking, critical youth participatory research methodologies position students to actively identify, study and shape solutions to the local problems affecting their lives. These methodologies are focused on uncovering systems of oppressions, and in supporting young people to learn about and act towards socially just outcomes for themselves and their communities. A cross-cutting tenet of youth participatory methodologies is shared authority in research processes, reconstructing relationships between adult researchers and youth participants as "collectives" (Jones et al., 2015, p 143). Another is the importance of preventing research from marginalizing youth and their communities (Cammarota & Fine, 2010). However, complex power dynamics and organizational challenges add risk to efforts to work *with* youth to solve problems. For example, the dual focus on seeking outcomes transformative to the conditions youth seek to study *and* the research/power structures they work with is sometimes lost. Identifying these cross-cutting tenets and endemic challenges is central to our work.

The field of critical youth participatory research methodologies encompasses a wide range of definitions, epistemologies, and approaches, ranging from the more widely discussed youth participatory action research to lesser used youth collaborative design-based research. Youth participatory action research ("YPAR") is the most well-known and widely used form of youth participatory research. In the theoretical tradition of critical action research, YPAR is a "social and educational process" for doing research in collaboration with participants, whereby adults and youth learn with and from each other in ways that challenge some important, basic assumptions about educational research (Kemmis & McTaggart, 2005, p 563). Galletta & Jones (2010) further explain that YPAR "recognizes the insider knowledge that young people bring to an inquiry of social and educational issues affecting their lives… [Y]outh are not simply informants in the research design, but are partners in investigating and creating bodies of knowledge" (p 341). The process of design, data collection and analysis becomes more fluid as each stage is opened up to critique and renegotiation from all research parties (Kemmis & McTaggart, 2005, p 563). The resulting greater number of diverse perspectives and ideas can enhance the quality and impact of research produced. For example, Sato (2013) showed how YPAR can be transformative for youths' STEM trajectories as they confront racism in science education. Rather than just identifying cases of racism in science education, youth and adults partnered to design and implement a plan to address it. In this process, youth co-researchers constantly renegotiated their roles based on skills, knowledge and expertise they brought with them.

Multiple researchers have also utilized critical youth participatory methodologies in science through critical ethnographies with youth co-researchers. Examples of critical ethnographies with co-researchers include youth who investigated urban heat islands and then educated citizens of their city in youth-centric and culturally sustaining ways to raise attention to the problem (Calabrese Barton & Tan, 2010), youth who developed a Green Carnival to engage their community on energy and sustainability issues while responding to particular needs and challenges faced by community members (Birmingham & Calabrese Barton, 2013), and youth who led the design and completion of scientific newsletters they distributed across elementary schools to deliver science content to peers in more engaging and relevant ways (Rahm, 2012). In these cases and others, youth applied science and research skills to real-life challenges while building complex understandings of the systematic forces at work in their education. These examples of working collaborations with youth transformed the research conducted and its outcomes, as well as expanded methodological inquiries through their participation and insights.

Critical youth participatory methodologies in science education have also been integrated into design experiment approaches, although to a much lesser extent. This design research has appeared in science education research, but few have included youth as co-researchers. This is an important gap to address, not least of which because youth co-researchers can reshape interventions with important perspectives that adults did not initially consider (Calabrese Barton & Tan, 2009).

Methodology: Critical Ethnographic Participatory Research

Social and spatial learning contexts are traditionally mapped and analyzed by researchers, not the youth who are experiencing them (Leander, Phillips, & Headrick, 2010; Langhout, Collins, & Ellison, 2013; Neal, 2014). In critical response to this tradition, I embrace youth participatory design and research traditions to recognize my participants as partners with agency and unique voices (Kirshner, O'Donoghue, & McLaughlin, 2005). I enacted this work through a social justice-informed perspective, using critical ethnographic methodologies and participatory methodologies. I call this combined approach *critical ethnographic participatory research*.

My terming is meant here as a specific descriptor. It sits separately from participatory critical ethnography, where the type of research would begin at its foundation as a critical ethnography but incorporate participatory elements. Describing this study thusly would be inadequate and inaccurate.

I use the term *critical ethnographic participatory research* to underline that at its essence, the study here was conceptualized from the beginning and conducted through to completion as a *deep partnership* effort before anything else. As described below, five youth researchers partnered with me to decide what type of research approaches might be most helpful for documenting, analyzing, and interpreting their lives, their efforts, and their desires for support as they work towards futures with STEM. What resulted from this shared effort is a new justice-oriented research approach created, implemented, and completed in *deep partnership* with youth researchers.

This was a critical Freirian attempt to re-envision what research with youth, about the life of youth, could feel like for both youth and adult researchers as well as what such research could affect or produce. We wanted to do research together that was imbued from the beginning with creative self-expression, mutual respect, and joy. We also wanted to do serious work that would be rigorous and thorough enough to represent and amplify their voices to adults who had the power to affect their lives (and the lives of other youth). Finally, we wanted to show the world how much our research was enhanced because of multiple years of deep partnership-building that stood behind it. I love those five young people, and I love their families. I am fiercely committed to producing honest work that honors who they were during our study as well as who they want to be in the future. For multiple years in a row before this research even began, we had been in each other's lives during about three days a week, every week. We had shared laughter and sadness, frustration and joy. I felt our deep partnership in my bones. The research about these young people's lives with STEM that interested me, therefore, was research that would result from joint decisions and open conversations. We could do better than tradition.

Coming to the decision to use critical ethnography as a methodological tool came from participatory work in three pilot tests and several planning sessions with the final five research partners. Youth partners wanted to share both positive accomplishments and upsetting structural challenges that framed their efforts to create STEM pathways for themselves. They wanted to draw from physical and digital artifacts that they felt could represent their efforts, but we also considered together how interview data could supplement and expand those representations (e.g., by serving as spaces to reflect on and co-analyze the artifacts). They wanted to represent their stories of life with STEM in their own words, but they wanted my help to write those stories. As Amara and Keke explained to me in one of the pilots, "We are the talent, but you can be our manager." We discussed other possible approaches and methods including but not limited to survey research, social network analysis, person-centered life trajectory mapping, mixed methods research using experience sampling methods, and art-based research via photovoice, 3D modeling, and graphic design. We all liked that we were already familiar with conducting critical ethnographic research from our experiences together in the Afterschool STEM Program, where youth-directed community ethnography is a design component of the program to inform and complicate their engineering design problem spaces. I also explained how the critical ethnographic approach sought to uncover power inequities built into sociocultural and historical frameworks of their lives. They agreed that addressing inequity must be a central aspect of this research, as it greatly affected their efforts to build futures with STEM.

I presented to them that a critical ethnographic perspective might also help us write about our participatory work (for my dissertation, and in a future co-authored book) with more nuanced attention to our different positionalities as a collective comprised of a White teacher and a group of Youth of Color. We had always talked openly about race, gender, class, sexual orientation, primary language, and other categories that created beautiful diversity in the world as well as our afterschool program. We had also, as a part of that program, openly discussed structures of injustice that divide people and inequitably distribute resources and opportunities along such categorical boundaries. After all, our afterschool program acknowledges that exploring multiple and intersecting forms of inequity is a crucial skill for engineers who seek to make the world a better place through community-oriented design.

While such transparency and critique was common practice together as STEM practitioners, I argued that it would be wise to seek out approaches that could help me more clearly notice and more explicitly talk through potential blind spots, power inequities, and other risks in our research partnership. Along these lines, Amara asserted in one of these planning meetings that our participatory process for conceptualizing the research together as a team from the outset should be a new standard practice for doing research with youth, an approach she hoped other adult researchers would pay attention to and try out for themselves. This, she added, should especially be considered by White scholars working with racially diverse youth. “This is not just some white person’s Black Lives Matter story. It’s our story we’re writing together,” she proclaimed, confirming our shared understanding of my responsibilities as her partner to share her truth without stealing or ignorantly warping it. I had committed to anti-appropriation and anti-exploitation in this scholarship, and she wanted other adult researchers to see how our partnership work was helping me make good on that commitment.

Academically speaking, the way in which we took up critical ethnographic participatory research partially drew from discussions of relational equity as a design tool (DiGiacomo & Gutiérrez, 2016; Dawson, 2014). I intended to address and challenge traditionally asymmetrical power relationships in this shared work (e.g., researcher-participant and teacher-student power inequities that can result in participant and student voices getting silenced or overlooked). Our youth-adult relationship needed to be reimagined with a critical eye towards seeking more symmetry, and opening up that work by "tinkering" together with approaches and tools for conducting that work could expand access so that we could co-examine the process and products of the effort together (DiGiacomo & Gutiérrez, 2016, p 144).

Critical justice approaches to equity helped us to extend this effort further by looking at how we could disrupt power hierarchies structuring educational research and STEM education (e.g., Calabrese Barton & Tan, 2018a; Milner IV, Cunningham, Delale-O'Connor, & Kestenberg, 2018). This included paying attention to who got to create the interview protocols we used, who got to decide what our research artifacts should include, and how data was examined. Youth in this study wanted ownership in the research processes and products, so we sought more ways for them to lead and me to follow in the research. We were able to rethink our research artifact construction process by drawing from our familiarity with youth ownership in maker processes and youth-adult collaborative reimagination in designs for change (Calabrese Barton, Tan, & Greenberg, 2017).

We also drew from Chávez and Soep's (2005) discussion of mutual accountability between youth and adults. Their "pedagogy of collegiality" involved youth and adults sharing in struggles together through collective work and collective responsibilities that were made concrete through literal, artifact-based coconstruction practices (p 420). In their study, the artifacts were radio program episodes; in this study, the artifacts were participatory pathway portfolios. In both, power inequities implicit in any youth-adult working relationship were still there, but those inequities were powerfully "unsettled" through our mutual vulnerability and mutual investment in a shared process and product (Chávez & Soep, 2005, p 420). This effort was greatly enhanced through longitudinal relationships, because we were able to build such relationships of mutuality over time.

The result of this take-up of critical ethnographic participatory research was a co-construction and a partial account of reality, in alignment with Rahm's (2012) discussion on the creation of a collaborative imaginary space between youth and adults. Our unpacking of "time-space configurations" was a shared effort in meaning-making (Rahm, 2012, p 254), one that required both youth and adult to "actively contribute" to the research (p 262). This was an attempt to answer the field's call for more approaches that aid researchers in imagining the future differently in partnership with youth and community. We wanted to "rupture[e] educational inequality" found throughout STEM learning spaces (both in and out of school) by representing and exploring young peoples' legitimate construction of STEM pathways across space and time (Gutiérrez et al., 2017). We also wanted to develop and demonstrate some new ways to challenge inequities in research relationships through "new forms of inquiry that help reconceptualize what it means to work with nondominant communities" (Gutiérrez et al., 2017, p 30).

This shared effort was also a form of critical praxis (Freire, 2007; Freire, 2014), a way of conducting social justice-informed work in partnership with youth. It involved recognizing young people's expertise in their own social and spatial contexts by inviting them to take on leadership roles in a shared project to explore and analyze those contexts. As Milver IV (2018) explained, "Students are the experts of their experiences… the teachers of their point of view" (p 12). We were attempting to describe the world around us, and Freire reminds us that in this effort, "no one can say a true word alone—nor can she say it *for* another, in a prescriptive act which robs others of their words" (2007, p 88). Describing the world could not happen unless we made our work "infused with love" through a shared dialogue of humility (e.g., recognizing my inability as a White woman and adult researcher-teacher to identify the world like the youth researchers could). Co-creation in partnership, with faith and hope, meant engaging in critical thinking together to decide the *what* as well as the *how* of our research together; I did not have the right to decide this myself (Freire, 2007, pp. 88-93).

These combined lenses helped me attend to power inequities implicit in any working relationship between youth and adults, and to the power inequities implicit in my positionality as a White, female, university-resourced graduate student working together with youth from marginalized communities. As described above, I embraced critical ethnographic participatory research as a new way to attempt a more humanizing stance towards conducting qualitative research with youth about their lives (Paris, 2010).

Context

We conducted this critical ethnographic participatory research within several layers of context. Addressing and drawing from a wide multiplicity of contexts allowed for a more multidimensional viewing of our shared work, by allowing us to acknowledge youth pathway practices as multilayered (Leander et al., 2010; Rahm, 2012), intersectional (Cho, Crenshaw, & McCall, 2013), and mediated by complex power structures across dimensions of social life (McCall, 2005).

Physical context. This work occurred inside of an after school, youth-designed, equity-oriented STEM makerspace. This is a location imbued with youth ownership and mutual accountability between youth and adults. It encompasses one large room within a Michigan Community Center (a community-based club focused on youth development, homework help, and sports for youth from low-income backgrounds).

We continue to house STEM and making programming within this Community Center because, as youth explain to us, it could be more easily described as their "territory" than other spaces could. It is imbued with more youth ownership than, for example, their schools, libraries, or parks. The lived experiences of youth and the particular cultural histories in the Center guide our work and open up interactions between STEM and youth spaces of practice that might not exist in other physical contexts (e.g., in a science museum). First, the Center and the makerspace within it are predominantly Black youth spaces with racially diverse staff, grounded in the community surrounding it and the adjacent neighborhoods in the South end of the city. This imbues the Center with a sense of shared, celebrated community and a willingness to openly commit to and discuss strategies for supporting Black youth in thriving. Youth have explained that the Center and its makerspace can be restorative after a school day of policed behavior and predominantly White, critically unconscious teachers. Many youth also attend the same church and/or the same school, so they spend afterschool hours with familiar peers and have access to a built-in backup support system of trusted adults through friends' parents (e.g., when youth get a phone call that a parent cannot take them home, there is often someone their parents know in the building, who they can ask). Furthermore, multiple staff members are former Center youth members who hold deep personal understandings of the importance of the Center in the lives of Youth of Color in Michigan.

Connected to this identity, the Center is also a space of community and care. For example, our program activities during the years of this study often drew in and were greatly enhanced by siblings, parents, and close friends of program members who visited from other areas of the Center (e.g., a younger sister who was enlisted as a product tester for her brother's arcade game design, a mom who happily jumped onto a sewing machine to help three youth troubleshoot the machine's tension issues during a wearable electronics design project, etc.). These visitors felt a shared sense of ownership in the makerspace because of their own personal, longitudinal relationships with the Center. Programming also often spread out of the makerspace and into other areas of the Center and its surrounding streets where the youth program members felt shared ownership (e.g., in order to gather community data via youth-created surveys on iPads and clipboards, in order to recruit cast members for a podcast about kid superheroes fighting greenhouse gases, etc.).

Youth have described their Afterschool STEM Program makerspace as a place within the Center where they can learn and grow while expressing their creativity with old and new friends alike. In interviews conducted by colleagues for other papers, for example, Afterschool STEM Program members described their makerspace as a non-judgement zone. This is a powerful statement to hear from preadolescent middle school students who have described school as spaces of judgment on everything from what they look like to what they are told they cannot do. Youth in this study described the makerspace as resourced with people "who care about you," including both peers and adults. It is also fully their space, as it was even originally designed (and lobbied for) by Afterschool STEM Program members a few years ago. See Figure 1 for youth comfort with the space illustrated.

Figure 1: Youth in the Afterschool STEM Program Makerspace

The makerspace is outfitted with design components youth chose during a makerspace YPAR (youth participatory action research) project, including a bright red “thinking couch” and bean bag chairs with a rainbow rug, cabinets they painted themselves, youth-chosen music, tools accessible at “heights kids can reach,” and large tables for collaborative teamwork (Shin, Restrepo Nazar, Greenberg, et al., 2018, p 60). These components were organized around overarching youth design goals for their makerspace to be welcoming, collaborative, fun/playful, a learning space that recognized their work’s iterative complexity, and an environment supportive of their efforts to “make a difference” and “save the world” through their STEM-rich making efforts (Shin, Restrepo Nazar, Greenberg, et al., 2018, p 60).

The makerspace serves as one site within an ongoing collective of partnerships for researcher-led, STEM/making programming across several sites, including a Michigan science museum, the Michigan Community Center mentioned above, and a North Carolina community Center. During the years of this study, I co-led an afterschool integrated STEM program at the Michigan Community Center, for youth ages 11 to 14 (middle schoolers).

Programming. During the five years I taught and co-led this afterschool STEM program, we most heavily focused on engineering for sustainable communities, a goal that incorporates multiple perspectives and the collective good as a professional engineering imperative (National Academy of Engineering 2010). This anchored our integrated STEM programming in engineering design as a tool for community engagement and improvement, but our programming content also drew prominently from community-based environmental science, public health science, civil and mechanical engineering design, digital design, and electrical engineering design.

Knowledge-building partnership. This study was also conducted within the context of a grant to explore youth pathways with STEM outside of school. Research sites for that grant included four sites in the United States (the Michigan Community Center and Michigan Science Museum mentioned above, as well as two sites in Oregon) and four sites in the United Kingdom. Workshops and ongoing meetings with researchers and practitioners across all eight of these sites, both in person and online, greatly informed how I approached this research. For example, hearing about young people's experiences and interests across the other sites inspired additional potential interview questions and analytical ideas that I then brought back to discuss with my youth research partners. For the purposes of this larger project, I co-generated in-depth STEM pathway portfolio data with a total of ten youth in Michigan who were actively involved in STEM programs outside of school and supported data co-generation for four youth not involved. The five youth included in this dissertation study are a subset of the STEM-involved Michigan ten. More details on that are located below (under "Youth Research Partners").

Participants and Researchers

Program participants. From 2014 to 2017, 64 youth participated in our STEM making program, of whom seven consistently participated for three or more years, 14 consistently participated for two years, and the remaining 50 consistently participated for one year (three from 2013-2014, eight from 2014-2015, 12 from 2015-2016, and 19 new members from 2016-2017). The youth were primarily from grades six through eight (ages 11 to 14), and all were from lower-income families. Fifty-one (80 percent) identified as Black, seven (11 percent) as White, two as Asian, and four as Biracial.

As participants, youth committed to sustained engagement in engineering for sustainable communities, a goal that incorporates multiple perspectives and the collective good (National Academy of Engineering, 2010). The youth engineers used community ethnography to embed local knowledge and practice into making and engineering design. They collaboratively generated ideas and questions that mattered to them, generated and analyzed data from multiple perspectives, and leveraged data towards defining more complex/constrained problems and possibilities. They moved into community spaces to explore problems technologically and socially, exploring STEM in culturally sustaining ways. They also moved into traditionally recognized spaces of professional STEM practice (e.g., the nearby state university's engineering labs) to explore connections between their current work and possible futures with STEM. As they worked on design solutions in makerspaces, community members of ranging expertise provided help, insight, and feedback on their efforts.

Youth research partners. The five focal youth research partners in this study were chosen from a larger pool of 64 youth who were all active Afterschool STEM Program participants at the Michigan Community Center during the years of this study.

I invited 12 youth from the 64 program members to participate in an international participatory research project on youth STEM pathways. Out of those initial 12, eight members remained involved for the duration of that project as Michigan youth leaders, along with additional youth recruited from the Michigan Science Museum. Of those eight, five agreed to continue with me in a more intensive and longitudinal capacity, to complete the study reported here. Decision criteria for choosing the 12 youth included the following:

- Interest in working towards a professional future with STEM
- Interest in doing participatory research about their lives and dreams
- Participation in the Afterschool STEM Program for at least one year before this study began (e.g., youth were welcome to join our program mid-year, but I did not invite youth into the project if I had only known them for six months)
- Interest in continued Afterschool STEM Program participation during this study (to allow continued participant observation field notes, and because many interviews occurred directly following program sessions, in the same room)
- Interest in an intensive working relationship with me (requiring late weeknight meetings at the Center and intensive work sessions during a summer vacation)
- Availability (interviews/meetings were easier to schedule when parents worked late, meaning youth had to stay late at the Center anyways)

Youth were recruited through my existing relationships (aiding recruitment & retention) and youth received stipends to support participation and retention. Observation schedules were designed with youth to enable a) cross-case commonality (for comparing across settings & national contexts) and b) local specificity (to capture the distinctive nature of individual youth and the informal STEM contexts in which they participate). Observations were purposively sampled to cover youth participation in partner institution programs (about 50% of observed time), other forms of participation (about 30%) and non-informal STEM daily life (about 20%). I and other team members of the international STEM pathways research project had extensive experience successfully working this way with youth (e.g., Tan et al., 2013).

As described in the section introducing the critical ethnographic participatory methodology used in this study, youth researchers served as partners in both creating and using the data co-creation methods. Over several planning sessions, we discussed and decided together on our research objectives and questions, our methods to collect, curate, and otherwise co-generate the data needed to answer those questions, and the methods of analysis that would help us learn from the data.

In terms of demographic details, two of the five participants (Amara and Keke) were high schoolers with whom I had collected critical ethnographic data since they were in middle school. The other three were still middle schoolers. All were involved in our Afterschool STEM Program at the Michigan Community Center (the high schoolers were teen program mentors and former members). Two (Jazmyn and José) had also held the title of makerspace designer, as members of the Michigan Science Museum's Youth Action Council (all five were invited to the council, and Amara and Keke attended the first two council meetings before deciding against joining). Of the Michigan ten, six participants identify as Black, two as White, one as Latinx, and one as Biracial. Of the final five research partners, four identify as Black and one (José) as Biracial. All of the final five participants came from low-SES-positioned families and resided during the years of this study in low-resource communities. All desired STEM-related futures.

Table 1: Youth Demographic Data

Youth	Ages during critical ethnographic data collection	Ages during participatory data co-generation	Racial Ethnic Identity	Sites of Participant Observation Data
Jazmyn	10-14	12	Black	Michigan Community Center; Michigan Science Museum
José	11-14	12	Biracial, Latinx, Black	Michigan Community Center; Michigan Science Museum
Sincere	13-15	13	Black	Michigan Community Center
Amara	12-16	15	Black	Michigan Community Center
Keke	12-16	15	Black	Michigan Community Center

The final five youth researcher partners, my research co-designers and co-analyzers, include Jazmyn, José, Sincere, Amara, and Keke. They are very briefly introduced below. A more thorough introduction for each will be presented in the following chapter.

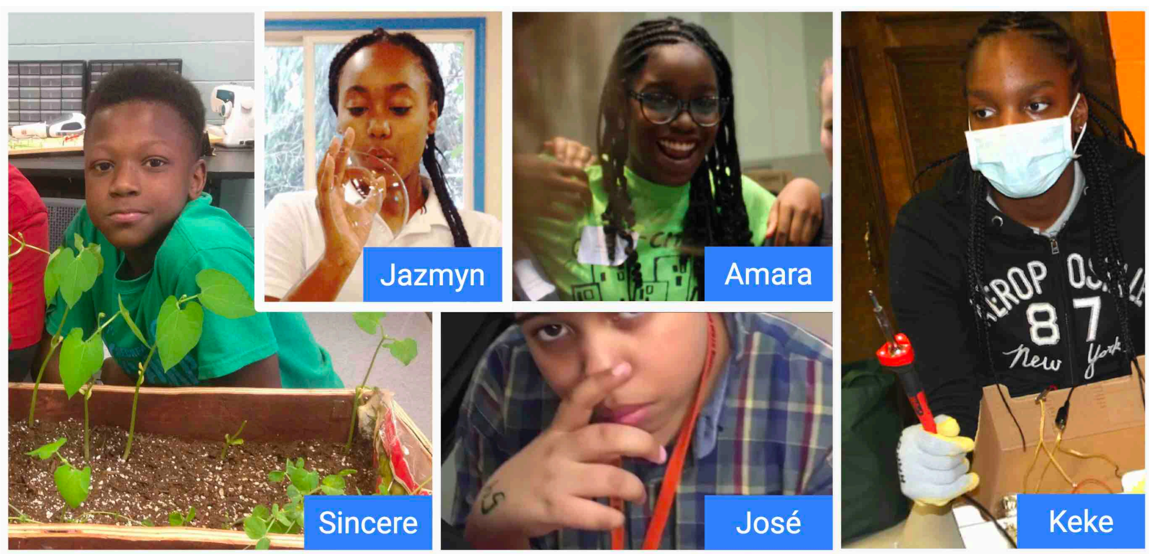


Figure 2: Youth Research Partners

Jazmyn. Described by her Afterschool STEM Program mentors as a social butterfly and leader, by her teachers as an advanced and gifted student, and by her mother and great-grandmother as a special superstar on the rise, Jazmyn's life pathway was highly supported by the adults in her life. She exhibited some aspects of what could be described as a traditionally supported STEM pathway, with consistently high grades in math and science, a full schedule of afterschool and summer STEM enrichment activities, and the attention of well-connected adults (e.g., her great-grandmother's leadership position in the Michigan Community Center aided in her bid to join the Afterschool STEM Program as a special fifth-grade helper, one year earlier than what was usually allowed). Jazmyn was passionate about a variety of interests and potential futures, including dance, cooking, engineering, chemistry, and community business development. During this study she began a new business as a painter taking commissions via her mom's Facebook account, and she passed an audition for the cast of her local cable access channel's hands-on science show, all contributing to her ideas about pursuing a STEAM career (science, technology, engineering, art, and math).

José. A self-described friend to all, José wanted me to describe him in this study as "a good karma guy" who would likely build a career as a "master of an army of bionic gerbils," a genetic engineer, or a justice-seeking technological leader he called "hacker of hackers." He sought a future of large-platform, worldwide exposure that would help him become more well-known and well-liked "by the ladies" and by the world in general. He explained that he wanted to bring his family honor and make his family name as recognizable and revered by society as STEM legends Bill Gates and Albert Einstein. He acknowledged that this would require raising his failing math grades, and during the time of this study his mom was saving for extra math tutoring. During this study, José's attendance in our STEM program was intermittent, but when he was there, he made his joyful presence enthusiastically known to all (e.g., with skips into the room, big hugs hello, dancing and singing while working, and offers to assist peers in troubleshooting). He also requested to become a teen mentor in our program at the beginning of his seventh-grade year. When I discussed with him the potentially awkward power dynamics of him offering his mentorship to eighth graders and the precedent of only high schoolers acting as mentors to middle schoolers, he presented the idea of creating a new Mentor-in-Training (MIT) program. José, Jazmyn, and their friend Wolf (one of the Michigan ten) volunteered as the first three members of this program.

Sincere. Elected class president in seventh grade and project leader by his peers in our Afterschool STEM Program, Sincere could be described as Mr. Popular. He used his advanced social knowledge and skills as a strategy to support his own desires for success in STEM (e.g., convincing more of his friends to join our program with the sole purpose of having more assistants backing him on his engineering design teams). He sought a future of economic prosperity, but even more important to him was a future in which "I will be my own boss." He hoped to be able to reach this future as an architectural engineer, and he took tips on self-direction from his aunt who he explained was a kind of electrical architect through her job of working with electrical circuit panels. Sincere was also a committed and loving older brother who often snuck his younger sister into our makerspace with or without permission, to check in with her as well as to get her opinions on his engineering projects. His relationship with her inspired his passion for designing for younger children's needs and interests and his passion for social justice through design in general. For example, his first major project was a miniature pool table to support younger children's play at the Michigan Community Club, and his second major project was a greenhouse prototype to offer more nutritious afterschool snack options at zero cost, for any young person at the club.

Amara. Described by her twin sister Keke as the "quiet" one, Amara's middle school passions included reading fiction chapter books and doing science after school ("not in school"). She wore prescription glasses, listened more than talked, and received mostly A and B grades in school, leading Keke to vocally envy her performance of the traditionally coded "nerd" stereotype, a stereotype that aided her in gaining recognition from Afterschool STEM Program mentors as an easily-defined advanced learner and thinker (e.g., I once witnessed two undergraduate mentors argue over who got to work with her instead of Keke). As she entered high school and took on a mentor role in the program, Amara explained that she felt a connection with the quieter program members, and she supported them in making their voices publicly heard. During this study, Amara was seeking a future as a pulmonologist specializing in pulmonary embolisms, a condition from which her grandmother passed away when she was young. She maintained extremely close friendships with two people, her sister Keke and Keke's best friend René. She hoped to live with them in a three-bedroom apartment throughout college (off-campus, to avoid distractions of college party culture).

Keke. Described by her twin sister Amara as the "crazy" and "loud" one, Keke relished in exuding confidence and unpredictability to both peers and adults. She sought more power and freedom than she felt she could access within the confining structures of school and Michigan Community Center rules, and throughout middle school she explored both sanctioned and unsanctioned ways to gain it (e.g., yelling at both school teachers and adult Afterschool STEM Program mentors). Or, put another way, she sought opportunities to take back power and freedom where she experienced a loss of it (e.g., running if told not to run in a hall, laughing loudly during quiet class time, etc.). She discovered a love for engineering through a hobby of "throwing stuff to break it" which quickly slid into "breaking stuff to see the inside" and to learn about how mechanical and electrical objects worked and were put together. She envied her sister's public recognition for fitting into respectability structures of learning and practice, structures built on White-and-male traditions of academic and professional productivity devoid of any outward emotional or social expression and devoid of any critique against power-holders.

But she also knew that she had a different set of skills that deserved to be recognized as equally important in STEM. For example, she entered our program with confidence in her electrical circuitry and mechanical design skills due to her lived experiences examining the insides of home appliances. In her first year in the Afterschool STEM Program, she investigated sexual assault against girls of Color and led a dual effort in anti-attack engineering design and public awareness campaigning to empower her female peers to speak out and speak up rather than remain silent and fearful.

Positionality of adult researcher. I am an educational researcher who identifies and has been publicly coded through life as White, ethnically Jewish, cis-female, English-speaking, and passing for heteronormative in racist, sexist, and homophobic societal matrices of power. While I grew up working class, during this study I was connected to and financially supported through the nearby state university as PhD student and graduate research assistant, a position that suddenly privileged my socioeconomic status in inequitable, classist structures of education and industry. My positionality informed my critical reflections on how I affected and interacted with youth in the program and in this study, in several, layered ways that required explicit attention and transparent dialogue.

First, as mentioned above, the Center and the makerspace within it are predominantly Black youth spaces with racially diverse staff, several of whom are former Center youth members. The Center is also, as mentioned above, grounded in the community and neighborhoods surrounding it, and many parents know each other. This was helpful to me in my continued development of critical whiteness (Matias et al., 2014). Entering this space and the relationships I built there (with youth, their parents, and other adults working there) demanded and continually helped me to hold a mirror up to myself, my thoughts, and my actions. It was daily motivation to recheck my assumptions, identify blind spots, examine and work to unlearn implicit biases, and realize a greater depth of responsibilities in working with Youth of Color as a White woman who grew up in a racist society that simultaneously espoused color blindness. I learned, for example, how discussing some of my experiences of Whiteness in life was a signal some youth needed in order to feel confident in digging deeper on a project about environmental racism with me as their partner. They knew that environmental racism was a topic that I wanted to examine critically together in shared trust, but I needed to share more evidence of my ability to do so.

Working in partnership with Black, Latinx, Asian, and Biracial adults was also an invaluable resource for me in multiple different ways, including as a source of relationships that helped me to enhance my own critical consciousness and cultural competency through continually reminding me in small and large ways that difference along multiple, intersecting dimensions is a crucial learning resource. I had grown into adulthood with a racially, linguistically, and culturally diverse group of friends and close colleagues, and I entered my first predominantly Black teaching space as well as my first community-centered teaching space with some naïve assumptions about my own skills and knowledge on critical justice partnership and anti-racist praxis. Multiple dimensions of this new teaching-and-research space were necessary components of an immersive re-education that improved my ability to be and act as a critical human and informed my practices for checking my power in relationships with the youth in this study. For example, in a series of conversations about publishing with a parent of a youth in this study, she illuminated layers of power dynamics I had not considered before (e.g., how me anonymizing youth data in an article about their efforts could be appreciated by their parent, while a stranger's book citing that article and discussing their child as an anonymous person could change the parent's feelings about the situation). Our transparent sharing within a long-term relationship of trust helped me to better grasp how the multiple and multilayered possible divides between *intent* and *impact* could be more thoroughly and continuously addressed in critically oriented research.

I joined the Afterschool STEM Program in my first year as a PhD student, and I taught there for 5.5 years. I worked to build, over time, long-lasting and trusting relationships with club leadership, other afterschool program mentors, parents, and youth. I sought out opportunities to spend time in young people's spaces outside the program (e.g., attending games, school plays, and community parties), and to bring them into mine (e.g., summer programs at the university, youth-adult co-presentations at research conferences, field trips, etc.).

As I fell in love with the youth I worked with, their families, and the Center's community, I was constantly invited into situations in which I was the learner (e.g., of important lived experiences, perspectives, hidden forms of discriminations I had not seen as clearly before, cultural capital I had not acknowledged or leveraged explicitly enough before, etc.). The "generative spaces" that our relationships produced provided me with a wealth of lived experiences in personal growth that echoed Sleeter's (2016) argument about Critical Whiteness as a continuing project: "[T]he present moments we all inhabit are anchored in a historical construction of racism that cannot be simply wished away. Yet, the self is highly complex…White identities are not monolithic, but rather laced with spaces for learning." (p 1067)

My years at the Center were arguably a more important education than the PhD I was simultaneously completing, but becoming a researcher in that space added a crucial layer of intersecting consciousness to that lived education. Working as a teacher and a researcher in the same space helped me to form a more complex praxis across both roles and also helped me to see and come to understand complexity in other people's lives. Through daily post-program field notes, weekly meetings with my advisor and research group, and weekly reflection-and-planning sessions with youth curriculum co-designers, I worked to interrogate the multiple and intersecting roles I took on as a researcher-participant. I also found many opportunities in those various moments to examine out loud how my identities and positionalities affected these roles and their outcomes.

The overlapping, dual role of teacher-researcher folded in on itself into additional roles including but not limited to collaborator, mentor, network gatekeeper, parental ally, youth ally, community ally, and critical participant-observer. I was a graduate student who was interested in exploring, analyzing, discussing, and presenting youth-authored representations of their STEM pathways. I was not only a co-researcher with youth—I also led programming as an afterschool STEM making teacher. This intersection of positionings increased the importance of keeping power inequities between youth participants and myself in check. For example, youth needed some forms of support and understanding as members of our afterschool STEM making program that differed from (but overlapped with) the support and understanding they required as participants in our research together.

Critical ethnographic field notes and researcher meetings were tools for reflexive iteration and growth in developing this study in critical praxis (Freire, 2014). Purposeful design flexibility was also an important tool aiding in a more critical application of participatory research methods, helping to ensure more equitable working relationships. It helped me to acknowledge that I had specific goals for this research and expectations about the type of data I wanted to collect, but that those goals were worthless without incorporating youth expectations and goals.

All of these lessons and tools took time for me to learn and build from, which meant that I could not have conducted this type of research during my first year of teaching there. I was just as eager to learn and just as committed to anti-racist, intersectional, anti-classist pedagogy and scholarship when I entered about 5.5 years ago, but the work would have been a lot more lacking in sight and hearing. For example, it took a long time to wrap my head around how much well-intended critical research and teaching by White adults was in urgent need of a complete reimagining.

Design Context

Workshops. This dissertation began with a series of researcher-practitioner workshops to explore youth access and equity in informal STEM learning pathways. Representatives gathered from a range of informal science learning centers (e.g., museums, zoos, afterschool clubs, science media groups) in San Francisco, New York, and London. We developed shared definitions of equitable pathways and ideas on what challenges youth might face in authoring pathways in STEM. Themes from reflective discussions included pathways as always in-the-making; pathways as diverse; critical or watershed moments, relationships, ownership/agency/choice, and resource infrastructure. All workshop representatives were invested in one goal: better understanding and supporting the complex pathways that youth were trying to create both within and across their diverse STEM organizations. In each of these workshops, I witnessed an entire field of practice wondering about the same knowledge gap.

There were some missing representatives, however, that might have helpfully challenged and advanced this industry-wide dialogue, with nuanced first-hand knowledge of the exact pathways under discussion. These missing representatives were the very youth they were discussing. We had an entire profession full of questions, with an urgent need to learn from youth directly.

This urgent need for youth expertise drove me to begin a set of three pilot studies from 2015-2016 that ultimately led to the study chronicled here. These were conducted as participatory pilots with a) the general student population at a state university in Michigan, b) a pre-med student who had gone through our Afterschool STEM Program years earlier and during this pilot was authoring what some science educators and researchers might define as a more traditional "successful STEM pathway," and c) a group of youth who were members of our Afterschool STEM Program during that pilot.

Pilot study 1: exploring multimodal representations. The purpose of this study was to crowdsource a range of perspectives from learners about their movements (their agentic efforts to navigate and negotiate) along/through STEM pathways in their lives. I created a public platform for participatory art to explore STEM pathways and how individuals represented them. I conducted this participatory art in a College of Education main building, a convenience sampling location to gather data from the general community. Participation was limited to volunteers who saw advertisements for "free doughnuts and participatory art" I had posted.

My protocol included the request: "Draw me a picture! Or tell me a story, or write me a short reflection, if you prefer that instead. Basically, I'm interested in your life history, your pathway, with science, math, engineering, or technology. What has your pathway been like with any of those topics? I'm studying STEM pathways, and I'd love to hear about yours!" If people said they did not enjoy those topics or did not interact with them currently, I said, "That's OK! I'm just interested to hear about what your efforts were like, and how they connected together to form a path that helped to bring you to where you are now. I'm specifically studying STEM pathways, but those pathways don't have to be positive. Feel free to tell me about your path with STEM however you want to express it or whatever it was like." I also allowed an alternative option of telling me a specific story from their pathway. When participants asked me for a further prompt, I told them, "What people, places, events, and resources/materials were really important to your pathway?"

In this study, people had some freedom of methods to represent their STEM pathways and how they were constructed. Some people took my initial prompt literally, drawing a physical pathway with connected lines indicating forward momentum toward their present, as well as shifts and turns that influenced the shape and direction of their STEM pathway as well as obstacles that pushed them out of a STEM-related pathway (e.g., landing them on a Language Arts teaching pathway, etc.). Some people represented their pathway as a singular written statement or formula, or with a powerful visual depiction of a singular, salient scene (e.g., an illustration of a classroom memory of feeling rejected by STEM). Some represented their pathway through a hybrid text/image comic book structure, and some in a reflective narrative in written text or spoken word.

This study informed my project by revealing how inviting participants' own words and illustrations opened up opportunities to uncover patterns in data that could be hidden or invisible in other data forms and methods (compared, for example, to social network analysis conducted by researchers using participant data). One such pattern that emerged was important "forks in the road"—moments, people and/or events that affected directions of movement in or through STEM learning and practice. For example, one participant named a specific high school AP mathematics class meeting as the key negative experience that dropped her interest in a STEM future down to zero. In her pathway representation, she explained that as a direct result of that single class, her self-efficacy in math suffered irreparably (i.e., she went from “natural ability” to “serious lack of math skills.” She also wrote, “no motivation to do math again” after that class, a feeling that she carried with her through her college years. My flexible data collection methods allowed me to visualize such data through participants’ own spatial and temporal lenses. As such, it produced powerfully honest and direct information on individual’s mobilities of criticality through time and space.

Pilot study 2: autoethnographic 3D and 4D pathway maps. The purpose of this study was to explore innovative methods to represent student mobilities of learning within and across one participant’s various learning geographies over time. In this study, I spent over 30 hours with an undergraduate pre-medical student and former participant of our afterschool STEM program. We were able to spend so much time together, as she was paid hourly as a summer research assistant in our research lab. As co-researchers in participatory artifact creation, our analysis involved several layers of complexity and iteration over time in order to peel back and examine the meaning of our shared work, what the results of that work showed, and how those results could inform future work.

The first stage in our multiple levels of open and constant comparative coding over time (Strauss & Corbin, 1998) involved looking across this student’s STEM pathway narrative that she had created earlier that summer. This auto-ethnographic narrative of her life journey in STEM became a helpful mapping resource. Together, we read through the narrative she had written, and in weekly co-researcher conversations, we discussed what stood out to us in order to identify salient aspects of her representation. Then, I helped her create nine coding categories from themes she had emphasized in her narrative. After coding her narrative with colors for categories and numbers for category importance for each event description in her narrative, we began creating data visualizations. The categories became component layers of pathway maps she designed, including four categories I had proposed (people, places, resources, and power). She added five more categories including "actions or practices," feelings of pride, obstacles encountered, social roles embodied, and a category she called "future" (preparations made, or future-oriented ideas thought). She diagrammed important events with those categorical aspects of each event as colored layers. Height represented each aspect's ranked importance to her pathway construction efforts (see Figure 3, right).

We discussed various methods and tools for representing her coded narrative visually, and we discussed and tested different materials and programs including Play-Doh, paper, Legos, Google Maps, Google SketchUp and MATLAB. Together, we designed several different types of STEM pathway maps as dynamic and color-coded layers of movement on top of her learning geographies over time. The maps represented aspects of her movements over time as different hues coloring dome-like formations. Each dome changed over time as a representation of different events occurring at the same locations across time. She coded connections between events and locations, showing what aspects and dimensions were important for bridging learning and development across spaces over time. Photos of the process are below (Figures 3 and 4).

As she explained in a resulting paper we wrote together for the 2016 American Educational Research Association conference in Washington, D.C.:

> "I call my pathway into medicine the "implicit" pathway because I did not have the usual experiences that help people get into medicine. My school did not have science fairs, and my mom did not have the financial ability to send me to STEM camps or programs beyond the free [afterschool STEM] program at the Community Center. Many

of my pre-med peers have already done things like work with medical research teams or complete intensive internships in hospitals. Many also have a family lineage of MD's or other science-related careers. They understand medical camps and hospitals, graduate school and MCATS, and they have a clear pathway to the medical world. I do not. There are days when I feel that, while I am surrounded by people who know what they are doing, I am in the dark, trying to find the right doors to open. There are days when I feel like an imposter. But, through hard work and with the help of many people around me, I still find myself here, and it is truly surreal.

I have been mapping out my science pathway. I'm doing this because although I never doubted what I wanted to be, I did doubt if I could make it there. I want us to show younger generations that even if they do not have the same opportunities as others, they can still be just as successful. I want to legitimize other pathways, not just the traditional route. Representing my "implicit" science pathway will help me show others that their nontraditional efforts are legitimate…

I also wanted to capture how "power" shaped my efforts. As an African American woman, I have had to push back against some of the stereotypes that society holds about me and what I can do. I feel that the topographic images that I am creating will produce a model that can allow all of these layers to be easily read." (Greenberg, Turner, & Calabrese Barton, 2016).

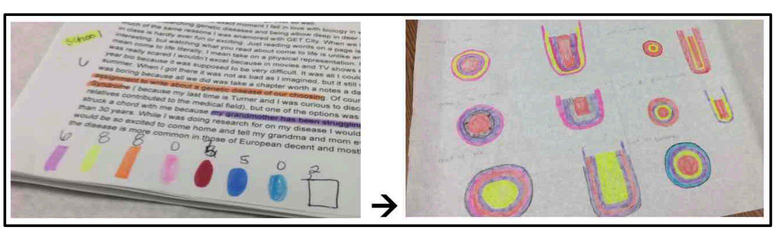


Figure 3: Youth pathway narrative, coded (left) and then visualized (right)

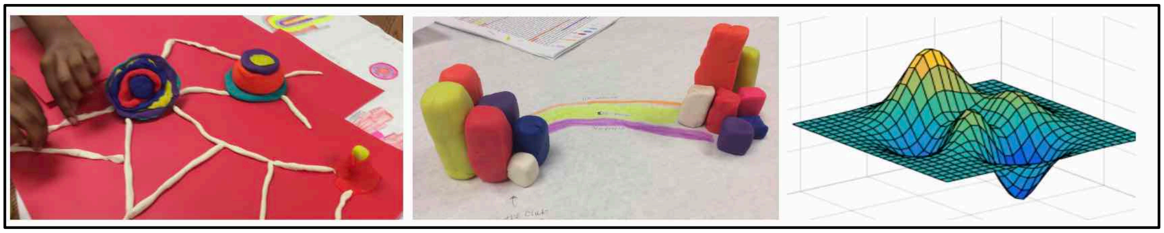


Figure 4: Additional, 3D pathway map visualization methods and tools piloted

This study informed my project by revealing affordances of different methods for mapping a multi-layered narrative of learning mobilities with STEM, both digitally and non-digitally. At the end of this study, I invited three current members of our afterschool STEM club to begin this mapping work as well. The biggest design modification I made was the addition of a 0-10 scale to represent each category's salience for pathway construction efforts (e.g., in building connections), besides my original power scale in relationships and resource movement. Next, I wondered how to incorporate directions of action and mobility across spaces and time, what participants named as learning and practices that mattered for their STEM pathways, resources they deliberately mobilized across learning geographies, actions they took to enter, exit, and take advantage of different spaces and places that populated their geographies, the roles and positions they assumed, and how these various efforts were recognized by others over time.

Pilot study 3: virtual reality game design. The purpose of this study was to test and further inform and refine STEM pathway representation methods with a group of middle school youth participants, to learn from their perspectives. In Pilot Study 3, I spent about 25 hours with three seventh-graders I had known and taught for two years in our afterschool STEM program, including Keke, Amara, and their friend René. I met with them outside of the program days to lead a series of critical ethnographic interviews and participatory artifact construction projects to better understand how these three young women understood their STEM pathways and how they were actively working to construct and author their STEM pathways moving forward. I asked them about their STEM pathway efforts in the contexts of their identities as young Women of Color (Keke and Amara identified as Black and René identified as Biracial), as students from low-income families, as daughters of single moms, as individuals who identified with STEM subject areas, as preteens encountering the dramas of middle school, and as best friends supporting each other as they continued planning and constructing their STEM pathways together.

Our participatory research revealed how these three young women, and other youth they know, are working hard to forge pathways of learning and development in STEM with agency and purpose. We uncovered ways in which adults who are tasked with assisting these youth (e.g., their science teachers) are often neglectful if not active obstacle creators. They also illuminated how some resources and moves that are most vital to their path-hacking work are not directly STEM-related (e.g., snacks as emotional resources, childcare from neighbors as mobility tools for youth leadership efforts, deliberate relationship leveraging as strategies for long-term access planning, etc.).

Keke, Amara, and René took me far beyond my original research goals for this study, leading to new ways of thinking about mobilities and pathways. As planned, participants provided artifacts and auto-ethnographic descriptions of which people, places, resources, events, and obstacles were important over time and place. Data also included individual and group interviews, as well as participant observations from 2.5 years as their afterschool mentor in a larger, ongoing critical ethnographic project in STEM learning and development. As co-planners, however, they rejected my piloted coding and data visualization procedures in favor of more dynamic, visceral, immediately impactful methods of engaging science education researchers and practitioners. They wanted to "force" others to dynamically *feel* their pathways—through their points of view—including the violent, dangerous, and hurtful blockades they navigated daily as they moved in and across learning spaces. They extolled the virtues of first-person-perspective, point-of-view (POV) video games like Grand Theft Auto for “really making people *feel*” other people’s or characters’ life pathways viscerally, as opposed to merely viewing those paths from a comfortable distance. They cautioned that more forceful tools would be needed to engender empathy from adults.

This study informed my project by pushing the boundaries of how I and other researchers in the field had conceptualized and operationalized pathways and how we represented pathways multidimensionally. It opened my eyes to the innovative use of new tools and methods for more youth ownership in participatory research.

Data Co-Creation Methods

The five focal youth and I worked together over the course of several years as design partners and as co-learners in STEM out of school, forming a total of at least 240 hours (about 480 for Keke and Amara) of critical ethnographic data collection and co-generation work together. To organize all of that data, we worked together for at least 10 weeks on an individual basis to develop participatory portfolios and narratives of youth engagement in STEM across space and time, forming a total of at least 160 hours of curation and writing work together. This was completed in the Summer and Fall of 2017, with further updates completed as a part of our co-analysis work in Spring 2018. See Table 2 for youth data contexts and Figure 5 for a data time map.

Following portfolio and narrative co-construction completion, I continued to meet with youth on a monthly basis as I continued editing their stories and seeking feedback through reflexive cycles of critical engagement through member-checking, follow-up interviews, and line edit-level critique meetings. This was supplemented by reflection meetings with my Dissertation Director Dr. Calabrese Barton, and by informal conversations and ongoing teacher field notes conducted throughout the dissertation writing process (as I continued to teach twice a week with the focal youth whose narratives appear here).

I discuss data generation methods in two phases. First I discuss the specific forms of data we co-generated in the Summer and Fall of 2017 as well as data I collected from 2014 to 2017. Second, I discuss the portfolio production process of 2017. Following the data generation methods discussion, I discuss our new data co-analysis process which occurred in 2018 and 2019.

Data types. During initial planning meetings for this project in Spring 2017, the original 12 youth and I debated what kinds of data would be a) most helpful for exploring youth STEM pathway efforts and b) most feasible within a reasonable research timeline and without interfering with other time requirements of life after school. For example, we discussed how creating a full-length, virtual reality movie about their lives with STEM could be cool to watch but might cut into homework time and all-important free hangout time with friends. I also informed youth that I hoped to benefit from critical ethnographic participant observations in fieldnotes I had taken after every session of our STEM-rich making together from 2014-2017. Finally, I shared my desire to interview youth in order to generate rich narrative data on their experiences, but I wanted them to help me create the questions.

Interviews. Each youth was interviewed individually by me at least three times over the course of 12 months. The interviews focused on youth pathway components and structures (e.g., people, places, events, resources, obstacles, goals, experiences of power dynamics, their efforts to navigate and challenge structures, etc.), perspectives on themselves and their pathway development over time, and reflections on their pathway representations and our participatory research process (see protocols in Appendix B). All interviews were semi-structured and conversational in format allowing youth and I to co-construct them as we engaged each other. There were times when I turned the interviews over to youth, to guide the conversation completely and/or to interview me. Each interview lasted about 45 to 90 minutes. Interviews were transcribed by me and by an undergraduate research assistant.

This required creating several different interview protocols co-developed through several meetings in partnership with youth, after I completed protocol first-drafts. Some of the youth partners did not care what questions I asked and left it up to me. Some had a wide variety of edits and additions. Additionally, some ideas and opinions were not thought of or shared until after initial interview rounds were completed, requiring additional interview sessions to address.

Participant observations/fieldnotes. I generated fieldnotes on each session the youth participated in at a) the Afterschool STEM Program in our makerspace at the Michigan Community Center, b) Youth Action Council design meetings at the Michigan Science Museum, and c) maker activities at the Michigan Science Museum's makerspace. These fieldnotes were taken between 2014 and 2017, and generally covered outlines of events and conversations as they took place across youth STEM projects. The majority of my fieldnotes were audio recorded on my cell phone's voice memo app during nightly drives home from the Center, that were later transcribed by me (or by a paid undergraduate research assistant if needed on shorter notice). These fieldnotes highlighted updates across all program participants, with more specific details on youth I had worked with or talked to directly. Because youth completed projects in small groups, program mentors distributed themselves evenly across groups; each mentor chose one or two particular groups to follow more closely and provide more consistent support across a unit.

All of the final five youth research partners had been in groups I had chosen or been assigned to, so my fieldnotes offered detailed data on each (e.g., confessions and concerns I had as a teacher after a challenging day, life updates that youth had shared with me, moments of youth learning and development that made me proud or surprised to witness, etc.).

Participatory notetaking. Sometimes I recorded audio fieldnotes while cleaning up the makerspace after a session, and program members who were still in the room or had run in to grab something they forgot sometimes jumped in to add their own reflections of the day to the recording (Jazmyn, Keke, Amara, and other program members all did this at different times). Program members knew that I took fieldnotes to help me write papers about our afterschool work together, so their additions were made with the knowledge that it was a contribution of their own perspectives to that research effort. There was a shared understanding, too, that my fieldnotes were much like me writing in a diary or texting myself, so they sometimes added comments to it for fun with no anticipated outcome. Often, youth commentary was shared as a point of emphasis after either a particularly positive or negative day (e.g., to share joy or frustrations in their own words), but sometimes just as an aside. This resulted in further direct quotes and opportunities for youth to layer their own perspectives on top of mine.

Group conversations. Group pathway meetings were opportunities to plan research goals and procedures as a team. They were also collaborative sessions in which youth discussed their pathways together, building on each other's ideas for richer data layering. Youth asked each other follow-up questions, added peer commentary to stories shared, and reminded each other about details of memories they had shared in their informal STEM learning. These conversations were transcribed by an undergraduate research assistant, and youth double-checked direct quotes for accuracy.

Artifacts. Three main types of artifacts were generated:

Work artifacts. These included artifacts from most personally valued STEM efforts and projects (both in and out of school).

Informal artifacts. This refers to artifacts specifically focused on STEM pathway work outside of school. This overlapped in many cases with the previous data item.

Photos and/or video. This was initially collected and populated in portfolios and written narratives by both youth and myself, but ultimate curatorial authority remained with youth research partners.

Narrative data. I took the first pass at writing narratives describing each youth research partner's life experiences with and in STEM learning and practice. This first pass drew most centrally from youth answers to co-created interview questions about their efforts to construct learning and development pathways through life with STEM. I then went through those narrative first drafts with youth, discussing together what overall feeling each story gave the reader about each youth partner and how we responded to that overall message (e.g., how accurately did they feel it portrayed their lived histories, what felt unfairly revealed or inadequately addressed, what felt totally incorrect or unimportant, etc.). After a second writing pass post-member-checking, we returned to the narratives together and repeated this process. Finally, we discussed what themes of their lives seemed to be highlighted or uncovered by their narratives, what that could teach different audiences about their experiences, and what we wanted to highlight more or differently for such an educational benefit to a still somewhat general or ambiguously defined public.

Table 2: Youth Data Contexts

	Jazmyn	**José**	**Sincere**	**Amara**	**Keke**
We met	Dec 2015	Nov 2015	Oct 2016	Jan 2014	Jan 2014
Critical ethnographic data collection began	Jan 2016	Oct 2016	Oct 2016	Feb 2014	Oct 2014
Hours of critical ethnographic data collection	240 hours (over 2 years)	240 hours (over 2 years)	240 hours (over 2 years)	480 hours (over 4 years)	480 hours (over 4 years)
Portfolio construction and artifact curation (edits into 2018)	Aug-Sept 2017	Sept-Oct 2017	Sept-Oct 2017	Aug-Sept 2017	Aug-Sept 2017
Interview: About Me (Past/Now/Future)	Aug 2017	Sept 2017	Sept 2017	Aug 2017	Aug 2017
Interview: Places/ Events/Obstacles	Sept 2017	Sept 2017	Oct 2017	Aug 2017	Aug 2017
Portfolio Updates & Reflections Interview 1	Nov 2017	Nov 2017	Oct 2017	Sept 2017	Sept 2017
Reflections Interview 2	Jan 2018	Jan 2018	Jan 2018	Jan 2018	Jan 2018
Critical Participatory Co-analysis of Narratives	May 2018, updates in December 2018 and May 2019	May 2018, updates in December 2018	April 2018, updates in December 2018	April 2018, updates in December 2018 and May 2019	April 2018, updates in December 2018 and May 2019
Site of portfolio construction (youth's main STEM location)	Michigan Community Center & Michigan Science Museum	Michigan Community Center& Michigan Science Museum	Michigan Community Center	Michigan Community Center	Michigan Community Center
All STEM programs youth participated in across their lives (mentioned in their portfolios)	School, Afterschool STEM Program at MI Community Center, MI Science Museum makerspace and Youth Action Council, School program at MI Science Museum, University Summer Program for Microbiology	School, Afterschool STEM Program at MI Community Center, School program at MI Science Museum, Michigan Science Museum makerspace and Youth Action Council	School, Afterschool STEM Program at MI Community Center, School program at MI Science Museum, Additional community center	School, Afterschool STEM Program at MI Community Center, University Summer Program for Medicine, Job in Afterschool STEM	School, Afterschool STEM Program at MI Community Center, University Summer Program for Medicine, Job in Afterschool STEM

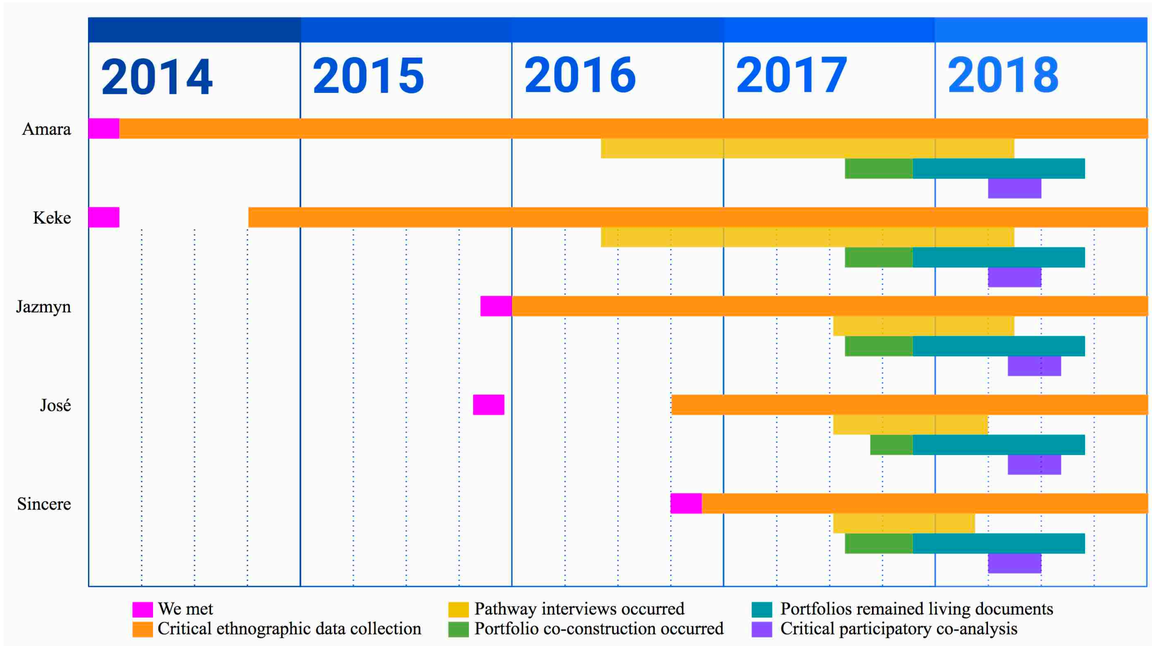


Figure 5: Youth data time map

Constructing portfolios. We co-constructed this collection of pathway representation portfolios as multimodal, critical ethnographic participatory cases. These portfolios drew from data we had co-generated over two to four years. Curating this longitudinal data, along with data from across their lives, occurred over a span of about 10 weeks. I hosted over 30 hours of group meetings to co-curate interactive digital artifacts. Youth partners mapped critical events, connections across events, and mentors and tools that supported their pathway connection-making efforts. Data included youth photos essays and written portfolio artifacts, youth videos and podcasts, critical ethnographic interview transcripts, and youth-adult co-analysis of more than 4 years of my participant observations and field notes as their afterschool teacher (averaging 120 hours a year).

As youth worked with me to co-construct pathway portfolios (collections of STEM pathway-related, data-rich, critical ethnographic artifacts), each portfolio was organized to include the following categories of information:

- *Introductory greetings.* Youth wanted to begin by welcoming their undefined public audience into their pathway representation. Youth determined how they wanted to introduce their pathways, resulting in several different forms of welcome including a formal title page, a formal introductory video, or a more informal or conversational message.
- *Introductory "About Me" data.* This included snapshots of most important facts or messages for unknown and undefined audiences to see and learn from instantly, before getting into a more narrative description of each youth.
- *Me now.* This data included critical ethnographic descriptive information on background, interest/participation timelines in STEM, community asset mapping, and science capital experienced during this study.
- *Me in the future.* This included written and drawn visions of future engagement with STEM as well as what they wanted to be and do in general.
- *Informal STEM learning experiences.* This included pictures of experiences and artifacts representing STEM experiences and movement across experiences, and reflections on the nature of those experiences.
- *Resources and Relationships.* This included text or video reflection on who, where, and what support their STEM pathway work. It also included reflections on how these resources sat in relation to each other and how they connected over space and time to support pathway construction.
- *Pathway Representations.* This category was opened up to include hand-drawn pathway art, three-dimensional digital renderings, and coded maps.

We co-created portfolios as multimodal, embedded cases, curating digital artifacts within an interactive, password-protected website format. We used mostly Google Slides for its user-friendly simplicity which enabled easy multimodal construction over the course of 10 weeks. Each week, I hosted two-hour group meetings at the Michigan Community Center, in Michigan Science Museum, or the nearby state university. Sessions were designed and facilitated to allow for multiple ideas, perspectives and relationships to co-guide the process.

Youth began by authoring a single STEM pathway portfolio "slideshow" from a co-developed "Part 1" protocol, written by me and edited by youth. This portfolio protocol prompted youth to identify people, places, resources, top moments, obstacles, future plans, feelings, and more. It also prompted youth to provide visual artifacts to represent those pathway components over space and time. As youth curated their portfolios, they brought in photos, video, audio, text, social media screenshots and more as artifacts of their STEM pathway work. In reflecting on the portfolio construction process, youth completed additional interviews from a "Part 2" protocol. This generated additional data on what their STEM pathways say about them, how + for whom they hope to affect change through sharing their pathways, etc. Co-writing + editing their own pathway narrative chapters provided youth-adult co-analysis of all this data. As a final step, some youth took action with their data, inspired by their own STEM pathway experiences (see Figure 6).

These portfolios served as a structure to organize pathway data into a presentation-ready format. We all wanted to present this research to multiple different audiences, so we decided that some kind of slideshow medium would be appropriate. But we wanted to make it more "exciting" both in terms of entertainment and in terms of sharing the complexity of our multidimensional work. So we decided to make it a multimodal presentation, including videos, GIFs, photographs of people and work products like prototypes, screenshots of social media and websites, drawings, emojis, blog posts, maps, full paragraphs of explanations to get all the good info out there, and the more typical slideshow media of bulleted info.

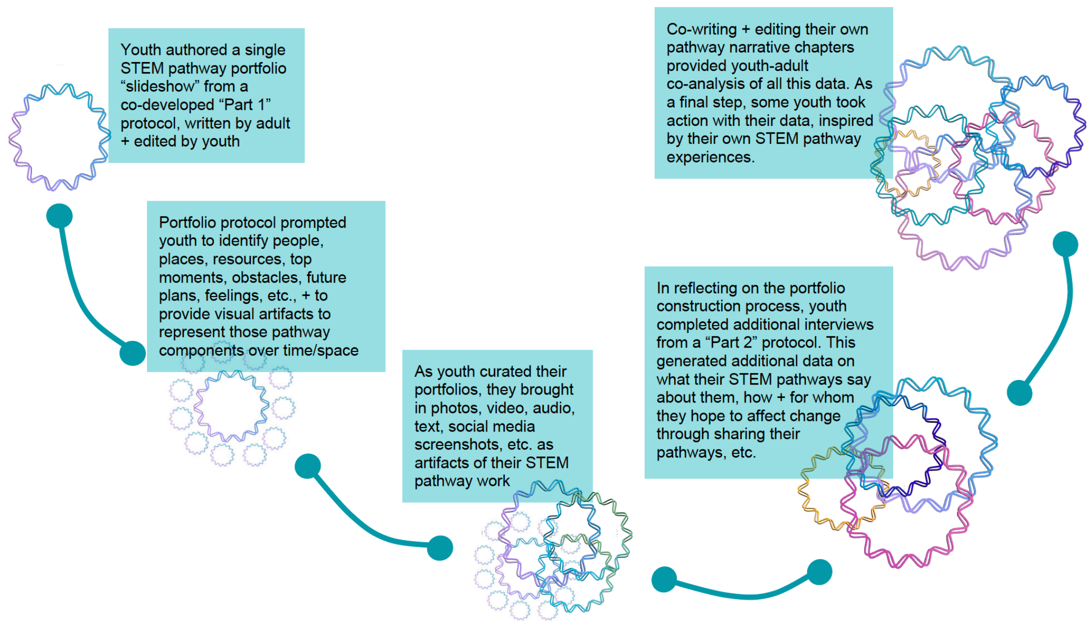


Figure 6: Youth Data Co-generation

Following portfolio co-construction, youth participated in a second round of critical ethnographic participatory work (late Fall 2017) including two components:

a) portfolio reflection conversations focused on critical moments and artifacts (c.f., Tan, et.al., 2013) to provide depth of insight into the opportunities they perceived as supporting (or limiting) ISL participation), and
b) continued pathway representation co-construction to add detail and to allow more time for optional alternative styles of representation.

Data Analysis Method: Critical Participatory Co-Analysis

Researchers have called for more frameworks and tools to explore challenges in STEM education (Feinstein, 2017; Philip & Azevedo, 2017). I offer *critical participatory co-analysis* as a transformative tool that led our research collaborative to new knowledge built from multiple data points and perspectives that had not been accessed by researchers before. This new type of knowledge is grounded in the acknowledgment of the legitimacy of youth expertise over their own lived experiences and pathway contexts. I ask that future researchers of youth pathways and ecologies take up such an acknowledgment, either through *critical participatory co-analysis* or using additional tools, as a joyful commitment to richer truths and more thorough power-sharing in participatory research on youth lives.

As I describe below, in this study, deep partnership with youth researchers drove what I am now terming a *critical participatory co-analysis* of youth STEM pathways and what supports them. I have consistently found that asking youth for their perspectives on topics, and their ideas for approaches to take, leads to more creative, more accurate, more richly detailed, and ultimately higher quality research. This type of research has also been more helpful to expand my thinking and investigation practices as a researcher.

In seeking to follow through on the deep partnership with which we began this study, I realized that I needed to reimagine what the analytical procedure of this study could be and include. This reimagining process opened me up to new understandings of possibilities for youth-adult co-analysis. I became deeply invested in working towards greater analytical power-sharing. Below, I detail the steps through which we enacted it.

First, a large part of what made this critical participatory co-analysis as rich and thorough as it became was the interwoven and inseparable contextual factors of our longitudinal relationships. These factors included, for example, the comfort level for youth partners to not only say "I don't want to answer that," or "Delete that part," but to actually tell me, "Day, that is such a stupid question and here's why" (I recognize critical refusal as the starting point, at the low end of what adult researchers owe to their youth partners) (Tuck & Yang, 2014). I partnered with youth I had known for at least two years (some up to five years). As described in previous sections, these relationships created a crucial foundation of trust through shared vulnerability that helped me to co-research youth lives as we continued to work together in STEM learning and practice. We were also able to mutually leverage these strong relationships we had built together to push beyond traditional limits of participatory research. Our shared interest in and commitment to making an impact that differed from other research on youth and STEM helped us to reimagine together what analysis could look like and create.

Step 1. Our first layer of critical participatory co-analysis involved conceptualizing life pathways together in reflective conversations during which I typed analytical notes. These conversations occurred before, during, and after curating multimodal pathway portfolio cases, as an iterative process. The curatorial decisions of what to include and how to represent it through portfolio artifacts were influenced by these conceptual conversations on what parts of life (good, bad, or otherwise) were important to include in a story about a STEM pathway. These conversations occurred separately from our data collection pathway interviews.

Step 2. Our second layer of critical participatory co-analysis included individual portfolio reflection interviews (using our co-developed protocols, Appendix C). These interviews were opportunities for youth to reflect with me on several layers of this research including a) the portfolios we had co-created, b) how our first round of pathway interviews had helped us to recognize and examine different pathway components of their lives, c) how our additional data types helped them understand and publicly represent those same pathway components in new ways, d) what they felt their pathways said about them, and e) what they wanted their portfolios to teach others.

Step 3. A third layer of critical participatory co-analysis involved sitting together in front of their written pathway narratives. I had written narrative drafts and completed a couple of rounds of edits in conversation with youth and my research advisor. Then I went through the narratives myself, coding youth portfolios with analytic memos for initial interpretations of patterns of pathway patterns. After adding these memos, I saved two versions: one with full memos, and one with memos shortened to communicate the main idea in each. I took screenshots of the short-memo-narratives in full-screen mode and imported the screenshots into the Mac Keynote slideshow program to share with youth. My intention was to make the narrative editing process less intimidating and less boring by chunking it to one slide at a time and starting with main ideas. Two considerations went into this decision. First, the youth research partners had used Keynote and Google Slides often and were comfortable with the format. Second, when I scrolled through text of their narratives as I was writing them in front of youth in our shared makerspace, I often received feedback that the narratives looked like "too much writing" and "boring" compared to their portfolio slideshows.

In these meetings with youth, we used red lines and red text to mark up the text together in Keynote as co-editors. Memos alerted us to potential themes I thought I had seen, which gave youth the opportunity to reject potential findings or alter them. For example, the potential theme of "multimodality" changed to "multidimensionality" through this process, because we decided that the former was more about tools, and the latter was more about how they saw and interacted with their pathways. In another example, "agency" changed to a more overarching use of the term "power" partly because I had changed memo-mentions of agency to power for better shared understanding with youth partners. Youth also liked talking about how many different types of power they experienced and desired, separate from their discussions of agentic action-taking towards structural change. We notated and highlighted components of their narratives that we both decided were important to their pathways, needed to be removed or explained differently, led to follow-up questions, or appeared multiple times. If a narrative component appeared multiple times, either within the same youth narrative or across multiple narratives, we considered this component as hinting toward potential themes and we added a memo about it, increasing its chances of landing on our final list of codes. This connected Chapter 5 descriptive findings to Chapter 6 analytical findings. At a midpoint in this process, our ever-evolving and expanding list of emergent codes included the following:

- Time
- Place
- Power
- Resources
- People
- Centering purpose
- Expanding purpose
- Action
- Change
- Learning
- Development
- Re-seeing
- Redefining
- Multiple dimensions, aka “living in 3D”
- Making an Impact
- Mobility
- Restructuring
- Ownership
- Pathway
- Future
- Past
- Present
- Hacking
- Critical moments
- Saliency/importance
- Identities/roles

Step 4. This process resulted in the development of our fourth layer of critical participatory co-analysis, which involved youth and me using the widened list of codes above. I took co-identified potential themes and used them as an open code list of initial patterns in youth pathway data. I conducted a cross-pass through all narratives and all multimodal portfolios, layering that with my multi-year, critical ethnographic, participant observation field notes. This provided for a more micro-level constant comparison (Strauss & Corbin, 1998) within our youth co-developed analytical framework of participatory co-analysis.

Relationships among codes were determined through a process of multivocal member reflection and member critique during follow-up individual and group conversations. In other words, youth also examined emergent codes, made connections between those codes and their data, and contested connections I had suggested. This was a new process to me, which added to our shared experience of doing something new with this research process together and made it more exciting. Our findings took shape as cross-cutting pathway themes that offered as a complex, multidimensional view of youth life while learning and developing with STEM. These cross-cutting pathway themes included the following:

- Time
- Space
- Power
- Resources
- Purpose
- Action-taking and change
- Re-seeing
- Redefining
- Multidimensionality
- Mobility
- Restructuring
- Pathway-related identity work

Step 5. Finally, I started to see how some themes were subsumed underneath other themes (e.g., restructuring was a type of action, multidimensionality became "seeing and leveraging more dimensions" as a type of re-seeing) and other themes combined equally into more complex categories (e.g., action-taking and change became action towards changing the world). Following this process, I organized cross-cutting themes into three sections of findings:

1. Navigating the world as it is
2. Creating the world as it could be

3. Outcomes of Becoming

See Chapter 6 for analytical findings organizing the abovementioned cross-cutting themes into those three sections.

Follow-up interviews and member-checking served as further co-analysis opportunities to examine structures that could better support them in STEM pathway construction. For example, when *power* emerged across the data as one of the most central and most cross-cutting themes of pathway construction efforts, I scheduled follow-up individual sessions with each of the five youth to ask them to elaborate further on how they understood and defined power structures framing their efforts; how they experienced empowerment and disempowerment in local and concrete forms; how time, space, and resources interacted with power along their STEM pathway development; how they enacted practices to affect this interaction; and additional considerations.

I achieved thick description by layering the data forms detailed above with other critical ethnographic data collected as part of our larger, continued research efforts in our makerspace. This included long-form interviews, participant observations, teacher field notes I conducted after every teaching session, and additional participant artifacts (e.g., collecting and analyzing STEM learning products like engineering designs made by participants who are also members of our afterschool program). These types of data assisted me in creating cases that served as examples of different types of pathway representations. Second, these data helped me uncover types of movement (e.g., people moving across learning settings and sharing their ideas across those settings) that I might not have been able to see through other qualitative research methods such as survey or narrative research methods. Third, critical ethnography and participatory research approaches are designed to identify and explore often-messy, intersectional complexities of disruption and difference (e.g., problems of too many overlapping or quickly changing variables to cleanly separate without direct guidance/input from participants or without methods that embrace longitudinal data). Topics in learning and development pathways (e.g., power structures, roles and practices of participation in those roles, actions of allies, etc.) came out more easily in descriptive data that was generated in a critical, participatory approach.

The participatory co-analysis developed in this study assisted me in achieving trustworthiness of claims in several different ways, all in alignment with the idea of "showing rather than telling" as a criterium of quality in qualitative research (Tracy, 2010, pp. 843-844). First, the process provided me with opportunities of showing credibility of the analysis through explicit connection-making between claims, direct quotes and richly descriptive examples from the youth pathway data, and related literature towards a triangulation-equivalent crystallization of findings across knowledge communities (Tracy, 2010, pp. 843-844). Related to this, the multivocality built into the design of participatory co-analysis, and our longitudinal relationships that lay the foundation for that work, acted as a guarantor of a more intense or deeper level of interpretation-collaboration with participants that resulted in a higher quality of claims (Tillmann-Healy, 2003). Tracy (2010) suggests that multivocality could be achieved in a process by which the researcher "seek[s] input during the processes of analyzing data and producing the research report" through soliciting member reflections and member critiques (p 844). The input-seeking process for our participatory co-analysis reached further than reflection- and critique-as-afterthought towards co-creation as central to our work along each step of research production. This allowed us to use member reflections as merely one of many, layered opportunities for building off of our foundational co-generation of data towards a co-generation of findings.

Reflection and critique continued over about 12 months of iterative development of findings through the participatory co-analysis process. These analytic steps are charted below in Figure 7.

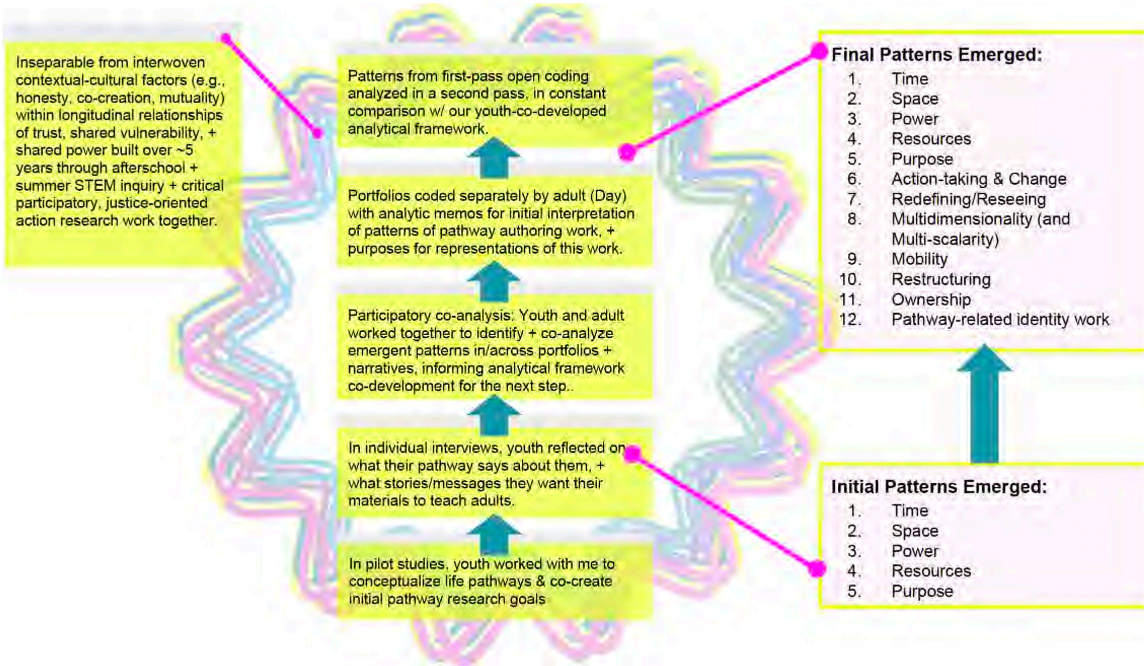


Figure 7: Analytic Steps

Internal Review Board

This study was conducted as part of my role of research assistant in a larger study to conduct research with youth in informal science learning across locations during 2017 to 2021 (National Science Foundation AISL grant 1647033). For youth I had known and worked with since 2014, we were also able to draw from their data I had collected in a previous grant from 2014 to 2017 (National Science Foundation AISL grant 1421116). Study participation was voluntary. Study participants had the right to withdraw at any time without consequence. They were assured of their right to refuse to comment or to answer any interview questions. Pseudonyms were chosen by participants to protect identities and to de-identify schools and other locations. Collected data remained confidential and were only shared with (a) the research group involved in the larger project and (b) with members of my dissertation committee.

Chapter 4: Descriptive Findings as STEM Pathway Narratives

Findings Presentation Structure

My findings include two connected parts. In the first part, I present five in-depth narratives constructed as descriptive findings from longitudinal critical ethnographies of youth lives with STEM, with an embedded case study design. I accompany these narratives with five longitudinal participatory portfolios as case artifacts (Appendix A).

In the second part, I present and explore emergent analytical themes from the five youth STEM pathways and discuss my response to theme emergence across cases. Following an initial discussion of these findings in context of my theoretical framework, I present limitations of this study before diving into some important implications for supporting youth pathways in ways that youth desire and urgently call for in this shared work. I end with some detailed recommendations for educators, designers, and researchers who wish to study and support youth pathways in and with STEM learning and practice.

Youth Co-written Narratives

In this section, I present five focal youth narratives, as participatory portfolio descriptive findings developed in an embedded case study design. These narratives were co-constructed with the youth as co-researchers.

As the following narratives show, each youth involved in this project took on roles of community and disciplinary leadership across different locations of learning and development over time. In this research, the leadership efforts they engaged in were crucial for helping me and other researchers and educators see what they saw and experienced in life and in STEM, as they worked to construct pathways to their desired futures with STEM learning and practice.

Jazmyn

Jazmyn is a socially connected Renaissance girl. During this study, she approached new spaces and new challenges in her world with equal amounts of curiosity, joy, talent, and interest. She sought outlets for self-expression everywhere. "I want to try every single sport and activity there is," she explained to me in a 2018 interview, while we viewed a video recording of her recent dance performance at a state competition and discussed her audition for our city's public access science education TV program. Her mom and other close relatives and family friends opened up access to a wide range of opportunities to cultivate her diversity of interests. That year, for example, one of her mom's friends gave her an acrylic painting set and blank canvases, asking for an "original Jazmyn painting" as payment. She quickly turned that into a new business selling paintings to family friends via her mom's Facebook account.

Jazmyn had "always grown up drawing and problem solving"—she immersed herself in those two practices so often across her life that it had become a part of who she was, "without even noticing." As an example of this, she described an instance in which a family friend had asked her to hold a spool of yarn for them while they knit. Not excited by the idea of manually rotating yarn for a long time, she came up with a quick solution to save her the annoyance: "You know how they have holes through it so that you can put it on a rack? I just got a pencil through it." She did not consider this to be a deliberate design optimization for improved performance efficiency; it was just her ordinary response to being presented with a problem. But the friend recognized this skill, "And then they told my mom I was such an engineer because of the fact that I just came up with that." This was evidence, for Jazmyn, that she had always acted like an engineer, "without realizing it." This personal history with engineering as everyday making and problem-solving practice was also a source of confidence for her when she discussed her developing expertise in interviews for this project: “I’m an expert in creativity because I can think of things easily off the top of my head. I can think of how to design things. I just do it so often in my life.”

Jazmyn loved art, engineering, science, and her afterschool STEM program. Her favorite food was chicken and phò, a dish she had once with her best friend’s Vietnamese family. Phò was one of a multitude of new things Jazmyn eagerly exposed herself to as she explored the world around her with intense curiosity. She described herself as an “easy-going, quick-minded, and intelligent” person who was “very interested in helping others” in her community. She was also “a rare species of artistic athletic nerd,” due to her wide variety of disparate out-of-school interests and activities from basketball to dance, from acrylic painting to circuit constructing. This spectrum of interests filled her out-of-school schedule with practices, performances, and even a new side business creating paintings commissioned by her mother’s friends via Facebook.

In our Afterschool STEM Program, Jazmyn was a popular friend and confident thinker. On STEM Club days, she entered the room with hellos, hugs, and light teases directed at peers and adults alike. In our group discussions about science and engineering topics, she engaged with elbows-on-table and hands gesturing for emphasis, leaning in towards the group with camaraderie. When she solved a problem or came up with a new idea to share, she shouted out with pride and requested the attention of someone to share that moment of joy with—usually anyone nearby, but sometimes a specific adult or friend who she knew would understand and appreciate the full context of the moment. In her independent or small-group work, Jazmyn moved about the room with confident posture, leveraging and remixing the resources of the space with a sense of ownership and initiative. On one afternoon in the fall of her sixth-grade year, for example, Jazmyn was in the middle of jotting down some notes at a work table, at the beginning stages of designing what would become her hand-built, wooden skee-ball arcade game. Suddenly she arose and skipped across the room, grabbed larger paper and a fine-point Sharpie from a craft drawer, and sat down on the makerspace floor to spread out while explaining that, of course, “big ideas need big paper.”

Jazmyn was also a trusted peer leader and adult helper in Afterschool STEM Program. On days when energy levels were abnormally high and concentration levels were abnormally low, Jazmyn’s social leadership and communication skills made her an easy choice for adults to turn to and call on as a trusted partner and as a seasoned liaison or mediator between adults and other youth. This sometimes involved Jazmyn assisting me in leading group dance breaks to shift the energy of the room (e.g., with an adult voice shouting “Woohoo, look at those moves Jazmyn’s got! Who else is joining us?”). It also involved me occasionally sharing with Jazmyn a “what a day” look or comment, to which Jazmyn laughed knowingly, or asked if I needed assistance with something, or sometimes took it upon herself to address an issue in question, as a representative for her peers (e.g., asking two younger, arguing teammates at her table to be kinder to each other).

Jazmyn’s pathway. Jazmyn’s pathway is just as much about the people around her as it is about herself, because she has not had to navigate STEM alone. Her desired future is one that encompasses a spectrum of pursuits, supported by the people who care about her in her community. She spoke fondly of that community and what it meant to be a trusted insider within it. She embodied the care, concerns, and wisdom of her community, and she sought to leverage that forward towards her own trajectory and that of those around her. These efforts often occurred in tension with the dominant narratives of what it means to be a Black girl (Morris, 2016). In the narrative below, I follow Jazmyn’s pathway work-in-action across focal spaces and times of her STEM engagement that she identified as important for supporting her efforts to be and become with STEM.

Pathway work-in-action: untraditional and multilayered leadership roles. Jazmyn's leadership skills shined in her engagement with the Afterschool STEM Program. I witnessed her use the program as a platform to co-opt and remix her available resources towards transformative outcomes for other youth at the Michigan Community Center, out of experienced necessity. Her efforts also supported her own development as someone with the power to challenge traditional constraints of STEM learning and to reconstruct STEM engagement with more joy and imagination than the spaces around her had historically offered to her and her peers.

In one example from her sixth-grade school year, as we were preparing for a community event for younger members of the club, Jazmyn decided to shift the event activities and boundaries, expanding the event's educational impact as well as her own role as a community teacher. The theme of the club-wide event was "Lights On," which the Afterschool STEM Program took literally, inviting younger club members to construct and learn about LED circuit design with different materials and activities. The event included light-up bracelet-making with felt, Velcro, and conductive thread; light-up greeting card making with copper tape and art supplies; light-up picture frame making with popsicle sticks and hot glue guns; a how-to-soldier-a-circuit station with supervision from teen mentors, and a how-to-measure-voltage station with multimeters, batteries, and a hand-crank generator. As the Afterschool STEM Program youth leaders planned this event one afternoon, different members excitedly called "dibs" on different activity stations. Jazmyn watched the goings-on and was disappointed that no one else was willing to take on the voltage-measuring station (the only station without a making component and with more of a mathematics focus). She volunteered to lead that station, and she spent the day refreshing her multimeter familiarity and voltage calculation skills. She went home that night with a pile of supplies from the makerspace, determined to make the multimeter activity "fun and not boring so kids want to do it, while still being educational." At the next program session, Jazmyn arrived with multiple curricular materials she had made over the last two evenings at home. "She's always doing something," her mom had later explained proudly to me about this effort she had witnessed late at night after homework was done.

Figure 8: Jazmyn's portfolio slide highlighting her multimeter station leadership

Jazmyn welcomed younger children to her station with three objects she had constructed herself: a light-up object-matching game, and a cardboard candy dispenser, and a brightly colored poster announcing: "Multimeters with Jazmyn." The game required players to attach the ends of two wires coming from a light bulb to two objects on the board. If the colors matched, the light bulb would light up. She constructed this game with a network of conductive copper tape, insulating layers of cardstock paper, and coin cell batteries taped in between layers. During the event, when a child got the light bulb to turn on, Jazmyn would take out her homemade candy dispenser and share a sweet treat as a reward. Then, she transitioned into her multimeter activity, telling her visitors that she was going to show them exactly how much energy flowed from different types of batteries. Finally, she passed around a hand-crank generator connected to a multimeter, and she invited her station visitors to compete and see how many volts they could produce. “Now they actually know why it works and why it happens,” she explained after the event, adding that “They probably didn’t realize it, but they actually learned” while playing with her station’s lights, circuits, and generators.

On the day of the event, in a quick debrief recording from the event room, Jazmyn stated:

> Today at my station, I taught everyone about multi-meters, which are right here, and I taught them how to use a hand crank. I taught them how hand cranks can make voltage like a battery, and I showed them how to measure it on the multi-meter to let them know what amount of energy they could have.

This was action to position her visitors as experts and engineers in their own right. As Calabrese Barton and Tan (2018) detailed in their recounting of this event, “youth at her table became animated” as Jazmyn invited her visitors to physically handle the multimeters, hand cranks, and circuits themselves (p 145).

Jazmyn created the experience that she knew younger community members deserved, one they would not have had access to in that way without her critical co-opting of lesson structures. She also leveraged the event as an opportunity to gain public recognition as a STEM community leader among younger peers. By reimagining possibilities for youth STEM learning, she restructured practices and boundaries of engagement in ways that expanded access for younger children at her Community Center. This effort was fueled by her interests in a) “being creative” and b) supporting more equitable community access to “having fun in life,” themes she emphasized in interviews for this study.

Jazmyn often sought out or was placed into such multilayered leadership opportunities, in ways that critically positioned her as a respected expert across multiple spaces. She was so dedicated to taking up, moving, and expanding on available leadership roles, that I sometimes forgot how young she still was (e.g., I sometimes had to remind myself, for example, that she was not yet a teen mentor and deserved more mentoring support herself). Her enactments of maturity and responsibility encouraged adults in her life to give her more and more community roles that packed her out-of-school hours (e.g., she also started a new neighborhood babysitting job during this study).

On one particularly overwhelming day for her, the then-12-year-old discussed some of the stress that she argued was always attached to her obligations and expectations. Much of the stress she experienced over time was related to her family role and “my position in the whole household” in tension with historical, sociocultural, and personal contexts that constrained other family members’ access and opportunities. As an older sister and half-sister with divorced parents, she was often privy to contentious power dynamics governing where, when, and with whom she could move (e.g., that week, a birthday party invitation had acted as a bringer of social conflict connected to power structures outside her control but still consequential to her and those she cared about). She discussed with seriousness her hopes to shield her younger brother from such tension and the sadness she connected to it, to allow him to enjoy the innocence of his youth as a 9-year-old. She understood that “as a leader,” she was being asked to navigate such tension by people who were counting on her (e.g., her younger brother who needed her protection). “I’m a trustable person,” she explained.

Navigating tensions interwoven in new opportunities became a familiar challenge for Jazmyn over the years, and she stated that more stress came with increased power. She explained, “I feel powerful when I’m accepted to do something that makes me feel a lot more mature,” even if it brought additional challenges. When her school recommended that she skip seventh grade, for example, the new eighth-grader entered spaces of bullying and prejudice that she had not experienced before. This included other students kicking her chair whenever she volunteered an answer in an advanced math class. She explained that she knew the bullying was rooted in jealousy of her skills and her access to more power than many of her peers: "At school I feel powerful the majority of the time in math class… Math is one of my many strengths." Her access to advanced study and public recognition by adult authority figures did not make her social life easier, but she valued the pathway development that such access and recognition supported:

> I have been told I have an amazing mind and I'm a creative thinker… I just feel like I got it all in the bag, you know? I can succeed easily. That just makes me feel powerful because I know like, I'm awesome and I'm a genius. You know, my dad still calls me a baby genius. So yeah… That's why I feel powerful because like they, one, trust me to do it on my own, and they, two, believe I can do it on my own just like I believe… They expect me to do great things.

With the positions of increased power she took on over space and time, Jazmyn discussed her desire to not give up any of the extra-curriculars in her full schedule that brought her joy as well as stress. For Jazmyn, her happiness was connected to the happiness of others, but she also liked feeling in-demand in multiple different areas of life practice.

Pathway work-in-action: designing community support with STEM. Jazmyn leveraged upon her experiences in her afterschool program to take on a wide range of expert roles with STEM. Beyond multimeter educator, other roles included public educator at community science events, entrepreneurial prototyper at city-wide showcases, Youth Action Council representative and makerspace designer at her city's Michigan Science Museum, live-television press chief at that makerspace's unveiling, and youth science education researcher at her nearby state university with this project among others. In this next vignette, I describe how Jazmyn sought to educate the broader community about homelessness and its impacts on people in her community, through her efforts to create the Donator App in her Afterschool STEM program.

As a sixth grader, when Afterschool STEM Program members decided to explore some broader-reaching issues of social justice, Jazmyn became a community representative and speaker on the issue of homelessness. She also became a targeted smartphone app developer working to address the problem in her city. This started with her and her friend's experience seeing an adult man on the street asking them for money. They were alarmed about being approached by a stranger, but they also worried about what that man did in the rain or snow. After some initial research online, they presented STEM Club mentors with the idea of a portable, emergency shelter design he could use, much like a wearable tent.

Jazmyn's STEM mentors, including me, pushed her and her partner to more thoroughly investigate the national and local/personal contexts, causes, and consequences of homelessness and transience in order to build a deeper complexity and closeness to the issue. Two of us had also had our own personal experiences being homeless, so we used ourselves as examples. I sat down at their table and told them the story of when I was evicted without warning from my apartment in New York City one morning, in my early twenties. An emergency tent would not have made me feel safe as a young woman alone on a city street or under a park tree. What did make me feel safe was having privileged access to a small network of friends-of-friends in the city, the contacts and resources made available to me when I asked. I didn't have money for a hostel or knowledge of local emergency housing services, but I had people connections that sprang into action and eventually secured a shower and bed for me that same night, in a friend's relative's apartment across town. I was able to go from scared and overwhelmed to relieved and grateful, because people who knew me had heard, believed, and shared my story with other people who had more resources to help me.

Jazmyn, her partner, and I worked together that session to try exploring the issue of homelessness with more depth as we wondered together what the experience of homelessness might feel like from multiple perspectives. They began by roleplaying what they might do and want in *my* situation, first as me and then as my friends. Then we searched online for examples of what homelessness can look like for a child, for a teen, and for a family. Beyond stigmas and stereotypes, we started to develop a shared understanding of how homelessness can look like real people with real stories and lives. They decided to design "the Donator," a smartphone app prototype to connect city residents with informational resources on topics of housing discrimination and other types of discrimination it connected to, community wellness challenges related to poverty, and impacts of homelessness. It would link users to external websites to learn more, and to tools to help organize donation and volunteering opportunities at local shelters in town.

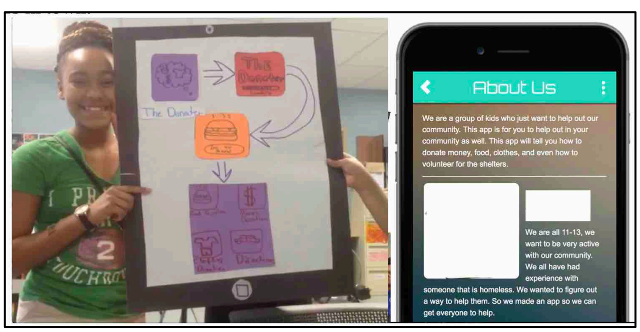


Figure 9: Left, Jazmyn's Donator app concept. Right, the app (de-identified)

With some research complete and a prototype designed, Jazmyn and her group partner convinced adult program mentors that a field trip to a local family shelter would be an important component in their investigation. I drove her and her partner to visit one of the family shelters in town so that they could meet with the shelter's communication director to learn more about how shelters work, and the needs and experiences of those who attend them. When we arrived, we took a tour designed for new volunteers. We walked through a large kitchen and cafeteria, a hallway full of classroom spaces, a Christian prayer chapel, and lobbies of apartment-style dormitory rooms for moms and kids. We discussed a partnering shelter down the street for only men, and a teen homeless shelter and resource center across town. As they walked through the shelter with clipboards and pens in hand, Jazmyn and her partner asked the shelter's communications director about numbers and ages of shelter residents, lengths of stay, reasons for coming, reasons for leaving, urgent needs and wants, and the shelter's long-term goals for itself and its clients.

Sitting together in a conference room at the shelter, the communication director discussed some ideas for how community members could use an app like theirs. She explained that the shelter's biggest challenge was city-wide misinformation and stigmatization around housing insecurity and homelessness (e.g., a stereotype of "homeless" as synonymous with "drug addict" or "alcoholic"). They needed help with changing the public's perception of people in need. She presented the two engineers with the shelter's monthly newsletter, which offered thoroughly joyful accounts of the shelter's community updates and events, as well as first-person stories written by individuals who had used the shelter's services and who wanted people to know more about their lives. The shelter gave the girls permission to use those stories in their app (names had already been changed for the newsletter), and they sent them off with a full year of back issues to help.

Post-meeting, the group's next-level app development incorporated their more recent and more complex findings, with a new goal to work in closer partnership with actual shelters in town and across their state. The most arresting new feature was an in-app library of personal autoethnographic narratives about experiences of homelessness. Later that year, two representatives from a state-wide homelessness coalition came to the Michigan Community Center to see their updated app design prototype and to discuss state-wide contexts and issues that could further inform their development work. They were impressed with the girls' depth of knowledge and their commitment to honoring individuals' voices and stories. The coalition offered the project team their resource assistance, their media outreach platform, and their continued guidance. Later that year at a city-wide showcase for youth entrepreneurs, Jazmyn's group revealed their app prototype to the public. They received further advice and/or business cards from city leaders, parents, teachers, and other youth entrepreneurs, and they proudly talked about their app and the work that went into it with whomever walked by. While the group did not win honors in any category, Jazmyn eagerly discussed her desire to attend more events like it in the future, as exciting opportunities to share her work and teach others what she had learned.

When I asked, in a later interview, for her reflections on what that project meant to her, Jazmyn described it as an empowering opportunity to physically leave her STEM learning space in order to leverage resources from across her city and connect them together for transformative outcomes. "I felt powerful being able to actually leave to go do research somewhere else [outside the Center's building]," she explained. "We were helping out in our community more. Like we were in homeless shelters asking questions to help us improve our app." Jazmyn connected movement across "real places" to her group's ability to better understand and act upon the tangible realness of their issue and how it was experienced by community members. In transforming their investigation from the immediately seen to the layers beneath, Jazmyn and her partner entered a journey to navigate several intersecting aspects of a social issue with the lenses of community-engaged scientists and engineers. In transforming their app into a learning platform, they took on leadership roles as both designers and teachers in and for their community.

Pathway resources: the importance of all the people around her. Jazmyn's pathway construction work took place within contexts of power-mediated sociocultural interaction with people, places, and resources. Important people in Jazmyn's life brokered opportunities and relationships that helped her access the resources that made her pathway work possible. For Jazmyn and for other youth in this study, people and the connections they brokered were the leverage-points for all other resources across space and time.

For example, when I asked Jazmyn about the STEM pathway supports that were most important in her life, she emphasized the people whom she considered her support*ers*. Her mother held the most significance to her pathway-constructing efforts, as a cheerleader and as a guide. She explained, "My mom teaches me a lot about how I am supposed to have priorities and like, make sure I put what I am supposed to first." With these priorities in order, her mom explained to me later, "the world better watch out" for her daughter, "the unstoppable superstar."

As I got to know Jazmyn's mom over the years and accepted her friend request on social media, I witnessed how dedicated she was to using her community connections to support her daughter's mobility and recognition. For example, when Jazmyn was invited to a scholarship-sponsored university summer program in biology, her mother posted photos and videos of her boarding the camp bus with a friend with the comment "My future engineer" (with hundreds of views and comments from family friends cheering Jazmyn on). One Halloween, Jazmyn made her mother a costume, which she posted with the caption "Can you say talented! #SheDidThat #FutureDesigner #Artist #SmartGirl #JazmynTheGreat." When our Afterschool STEM Program director tweeted a photo of Jazmyn in a large group of her fellow "Youth building a more just world" after they had presented on their community research at a local university, her mom was the singular parent in the photo, standing with her arm around her daughter's shoulder. Jazmyn's great-grandmother was seated right beside them. Her mom had switched shifts at the hospital to make it there and had driven Jazmyn's great uncle and great-grandmother with her as well. She re-posted the photo on her own social media newsfeed, adding, "look at my baby." Jazmyn once joked in an interview that her mom "brags about me and my brother a lot… She kinda thinks that I'm the leader, like the literal leader of [Afterschool STEM Program]." She added with confidence, "I *am* the leader of some things."

Figure 10: Left, Jazmyn with her mom and brother; right, Granny

Jazmyn's leadership roles were also greatly influenced by her great-grandmother, Granny. Jazmyn grew up spending several evenings a week after school in the Center's kitchen, where Granny held a respected position as club chef/kitchen manager. She used this time to ask Granny questions about homework and friend drama, help to serve food to older youth when allowed, and learn about life in the world at her great-grandmother's side. Looking back on how this history-in-place painted Jazmyn's pathway of experiences, she explained:

> I've been at the Michigan Community Center for a long time and they've always expected me to be the good person that I am. So…like, everyone holds me to a high expectation and they know that I can meet it, so if I don't, it's not like that they don't believe in me anymore, it's just that they're disappointed, but they still keep up those high expectations for me to succeed. So it's a lot of people who believe in me and hope that I can make it.

This community support was exhibited when Granny campaigned to get Jazmyn into our Afterschool STEM Program a year early, as a fifth grader. "She needs something to do," Granny appealed to me one afternoon, "and she likes science." Nearly anyone who spent any time in the Center knew her great-grandmother, who insisted on being called Granny by everyone in the club's diverse community, from children to adults. At the Center, "Whatever Granny says" was a common phrase, and with the support of our STEM Program director and the president of the Center, Jazmyn joined our program early. She began as a "special helper" like José, but because she was at the club every single day, she benefitted from that more consistent presence and her special helper role quickly transformed into more of a "junior member" role.

How Jazmyn projected her pathway efforts across scales. As Jazmyn leveraged her social connections and her community positionality, she recognized her efforts as disrupting traditional pathway options for herself as well as for others. She accomplished this structural change through a) seeking to reach and include others (and educate others), and b) extending and expanding her work over time. These efforts projected her pathway construction outward so that others could explore new ways of being and becoming in STEM along with her. This was demonstrated, for example, in the vignette about her multimeter station work to reconstruct STEM learning in more youth-centered and engaging ways that invited younger peers into the enjoyment she felt in STEM and expanded possibilities of how an introduction to energy flow and voltage could feel.

Another example of this impact-making through advocacy work began during her first year and created ripples that expanded still years later. In the fall of her fifth-grade school year, our theme was community safety. Jazmyn explored the problem space of home security for children and families without cell phones, and she worked with two older girls to investigate how youth could address this problem with technological design. Partly due to her near-perfect attendance at the club as a staff member's kin and partly because of her expert social skills and her willingness to take on a larger share of work, Jazmyn soon moved into an accepted position as group leader and representative. The older girls verbalized their confidence in her ability to make design decisions on her own and to move ahead with the project on days they couldn't join her. With her guidance and commitment, they progressed investigation and design processes quickly, eventually creating a novel one-button, 911-dialing device that can be hung on a living room wall and hit in the case of an emergency. The device worked by Bluetooth through an Arduino circuit that Jazmyn teamed up with an adult mentor and her teammates to program. It also included a GPS signal so that emergency respondents could locate the call instantaneously and without words shared.

Jazmyn expanded our age-defined boundaries even farther by inviting club members much younger than herself into the room throughout her group's design process that school year. These younger peers helped to test the prototype and share their feedback. They also auditioned for a short infomercial Jazmyn modeled after the talk show *The Real*, starring four female comedians of Color. The adult mentors in STEM Club stood around that day watching with interest as Jazmyn commanded about a dozen younger children, including her little brother and a younger cousin, to take turns sitting in front of a camera and running lines of script her group wrote. This cousin was also in the crowd in 2017 when Jazmyn presented her large portfolio of community engagement work alongside six other STEM Club youth. She approached me at that event and reminded me of her role in that early project, presenting her bid to connect herself to Jazmyn's resources, relationships, and demonstrated success as a bridge to gain access to those resources and opportunities for herself.

For the youth Jazmyn inspired and mentored, her efforts illuminated some of the ways in which power could be made available to youth in out-of-school community programs and projects. She also provided other youth in her community with some explicit examples of what can be transformed when youth use that power, and some tangible opportunities to use it in different ways over time and space. For her younger cousin, the chance to assist with one of Jazmyn's acclaimed community engineering projects was a chance to see what scientists and engineers do as well as a chance for gaining recognition by joining in their efforts. Years later, this young person reminded me of the concrete impact Jazmyn achieved in her community with science and engineering. Her cousin was a vivid example of that impact, standing in front of me and the institutional powers I represented and proudly claiming her own evidenced power as a worthy STEM person.

Sitting together and discussing Jazmyn's hoped-for impact of her pathway data, she stated that she wanted other youth in her community to feel the power of others holding high expectations for them. She hoped that this project could be a way to project her high expectations to other youth "like me," including Youth of Color, young girls, and "other kids in the future" in general:

> I want to teach people that they can have a great future… I hope people will learn that you shouldn't be afraid of what you want to do, especially if others joke about it. You should just do what you feel is right. Rather than think about what others want you to do… You can pursue a dream… You can be whatever you want to be… [P]eople should be able to do whatever they want to, like whatever they put their minds to, and not let others take control of their life. And they shouldn't be afraid to think of a new thing that's better for everyone. And they should be able to not live in doubt. …You shouldn't live in doubt. Whatever you think is a good idea, try it first and see the results.

Jazmyn often felt stressed from such high expectations to make her family and community proud, but as she explained above, she considered it counterproductive to doubt her ability to live up to their expectations for her. She was aware of society's discriminatory assumptions about young Black girls like her, and she was grateful to be embraced and surrounded by people who believed the opposite about her.

This collective belief in her gave her a defensive shield against the world's injustices that she knew other "youth like her" did not have access to. She called upon the lyrics of the song that she had danced to, in the performance video her mom had sent to me, as a rallying cry for youth in her community:

> I am not a stranger to the dark…
>
> We are bursting through the barricades and
>
> Reaching for the sun (we are warriors)
>
> Yeah, that's what we've become

> I won't let them break me down to dust
>
> I know that there's a place for us
>
> For we are glorious
>
> When the sharpest words wanna cut me down
>
> I'm gonna send a flood, gonna drown them out
>
> I am brave, I am bruised
>
> I am who I'm meant to be, this is me
>
> Look out 'cause here I come
>
> And I'm marching on to the beat I drum
>
> I'm not scared to be seen
>
> I make no apologies, this is me (Paul & Pasek, 2017).

Jazmyn suggested that I could look up the lyrics and add them to her narrative or play the song when I present on her data. She explained:

> The song is about believing in yourself. It's pretty much saying I am strong, I am different, and I don't care what people think. I will be me no matter what and I will fight for what I want. It represents kids all over the world because everyone is unique, and everyone has a voice.

When I asked what she was different from and what she had to fight against, she emphasized assumptions about age and gender as active barriers she had to break down in her social interactions across space: "I'm extremely smart for my age… which for some reason can intimidate people. Lots of people are shocked that I'm smart because I'm pretty." Race also intersected in tension with her efforts ("I still see the ugly in the world"), but her family and community's enactments of collective wisdom shielded her from directly internalizing some of the systemic racism she saw in that broader world: “I haven't really heard any assumptions about my race or me having to act a certain way because of my race… More so just assumptions about girls,” she explained. Furthermore, she added that moving into high school early was a challenge for her not as much socially (“I usually would hang out with kids older than me [anyways]”), but more so academically, “because I have to work harder than everyone else. Because now I have more eyes on me since I was moved up.”

One strategy that Jazmyn used to navigate her varied and multilayered forms of stress came from a method she had observed at a university summer STEM program:

> There was this big board and it had a bunch of sticky notes on it, and it says, “Take what you need” at the top, and it has a bunch of encouragements, and I took one about every day and put it in my pocket. So sometimes I lost it, but I still had one that I kept so when I got home I put it on my wall and it says, “Be yourself,” and like, the night I had encouraged myself to not worry about my depression and stuff, I put another sticky note on my wall that says, “You got this,” or “You can do it,” just to like, encourage myself a little bit more. So I can like, stay confident and like, not worry about everything else.

This simply strategy had become a central pathway practice in Jazmyn’s life, a resource leveraging act that she carried with her across space and time to inform and support her pathway efforts.

Later in an interview, she explained that these types of small practices could make a big difference in restructuring the world and opportunities within it, for her and for others. “I want to change the world by the simplest things. I want to be able to do simple things to help a lot. Simple can help a lot,” she explained. Just then, Sincere, José, and a couple of their friends entered the room where we were interviewing. She turned to them with a smile and asked: “You wanna hear the best quote in the world? I want to do the simplest things, to help a lot." One simple thing, for example, could be this pathway representation inspiring other youth to envision their futures in more expanded ways:

> Other kids in the future can see what they, like actually, should be looking forward to. For example, [friend's name] does not know what great opportunities he has, and then you start asking him these questions, he gets to thinking like, "Wow, that is a great idea." And he becomes great at that and takes on a career in X, Y and Z. Because of this pathway project.

A few months after that interview, she came to me with an idea for another "simple" tool she could create to advertise access to this pathway work, in order to expand opportunities for others to try out new ways of being and becoming towards their own desired futures. She made an introductory video to present her portfolio to other youth who wanted a bright future and were working hard to reach it: "For people like me, this [work] is for you." She added that it was also about educating adults who want to support youth like her, "so that they can help you be you."

How Jazmyn imagined her pathway's future. Jazmyn saw her pathway as helping her to "make the world a better place" by continuing to lead and create things that benefit her community, and which would draw upon her diversity of interests. She imagined a near future where she would team up with all of her peers who enjoyed creating, to make a tangible impact in her city through collaborative design practices.

When she and a group of Afterschool STEM Program youth leaders presented on their out-of-school research portfolios at a neighborhood event in December 2017, Jazmyn stood in front of a packed crowd that included her mom, her grandmother, her great-grandmother, her younger brother, a few of her cousins, and other youth and adults from across the city. Facing this audience packed with pathway supporters, she shared a vision of the Jazmyn of the future. She would design a community center much like her beloved second home at the Michigan Community Center, but one for families and friends of all ages to enjoy. This gathering place would be a center of happiness, one allowing her to continue exploring and developing her diverse interests and skills while inspiring and leading the people of her town. It would also include a restaurant with affordable prices, and a store to sell "clothes I've made, art I've made, and inventions I've made. And then have an open stage in the middle for people and myself to perform in." She would donate food from the restaurant to homeless shelters, and clothes from the center as well. "And of course," she added, "maybe I'll be the head chef too."

José

I want to build up to success, because success isn't a straight line.

It's a squiggly line that never ends.

- *José*

José described himself as a collection of different types of people, a fluid collection of different types of Josés whom he needed to create in order to respond to the various power-mediated contexts he found himself in. Sometimes these different José's coexisted and overlapped; sometimes one José took over while another José took a break. For example, José was "a good engineer" when he felt "really creative," and had the time, space and resources to try to build something or figure something out. This José liked "making stuff," including drawing everything from favorite animé characters to technical blueprints of what he wanted to design or build next. This José also felt interwoven with a Future José who would be a professional engineer, and his awareness of his drawing skills gave him confidence that he "can professionalize in making blueprints."

José's diversity of selves was a developmental strategy he used to respond to the power dynamics at play in the different worlds that populated his STEM pathway. He leveraged his developing understanding of how navigating one world in particular ways could enhance his chance at success in another world. This compartmentalization was a way to safely reject power structures' efforts for him to internalize norms that expected him to act, talk and be in a way that rejected his lived experiences in the world, as a young man of Color and as a complex human who wanted a future with STEM.

José in school. In school, José was "a very respectful student—at times." Sometimes he was positioned as "a good student" within the power dynamics of school that required obedience to authority. This José listened quietly and tried to "work together as a good team" with peers, within his learning space's rules. But when teachers or students would "mess" with him, he would "snap." This José was problematic ("I can control it, but it gets me in trouble sometimes") but also protective in a space "where some teachers can understand me, but other ones don't." Finally, School José was "somewhat of a procrastinator" which drove his development of strategies for getting tasks done quickly under deadline, survival practices he also described as a form of training he planned to leverage in future jobs. It helped that he was "a fast learner."

José at his community center. José took advantage of the different informal spaces afforded to him to engage in STEM in ways that mattered to him and his desired future. At his Michigan Community Center, José was "an Afterschool STEM Program member, in one of the best programs for engineering and green energy." This José "ha[d] to be hardworking." He "need[ed] to be focused and working hard," and he learned "how to respect other people's ideas." This José was also reportedly excited when working on a project and "mad" when the program was not in session, because "I usually have nothing else to do and I like being in here, working with friends in here [where] it's all about science, some people's favorite subject—shout out to the science lovers." It was also where he found "the rarest teachers in the world who actually understand me the most. So that's the main reason I come…And to chill and do work."

Figure 11: José (right) with a teammate in the Afterschool STEM Program

Afterschool STEM Program member José, also known as "José in engineering," was a coalition member and a colleague: "We all listen to each other's ideas and we work together as a team." This José used the word "we" in almost every sentence describing who he was, who he was becoming, and what he did. Many of his actions revolved around communication with others, such as discussions with project partners on "how the plan is going to go down" in which "we prepare each other for what's going to happen" before engaging in scientific investigations and design work together. For example, when José and his group were co-creating a solution to a problem, their working process embraced failure-and-revision cycles as a guarantor of eventual success:

> And when we run out of plans, we just make a better one, and we make another one in case that new plan fails too. If that new plan fails, we're just going to keep on going until we succeed. Like they say, if you don't succeed the first time, try, try again. I do that in engineering.

José at home. At home, José used science, engineering, and math to get tasks done more efficiently, and he connected his daily, ever-developing forms of STEM engagement to his more public engagement in other spaces. For example, when he threw away trash in his kitchen, he explained that, "I throw it far into the trashcan so I don't have to walk over there, so I think about angles and I have to measure how it's going to land in there when I throw it, so I don't miss." He threaded this way of thinking, doing, and being with STEM across time and space, explaining, for example, "We have to figure out the physics and angles of how we're going to build stuff in Afterschool STEM Program, so that's connected to how we work."

José at the museum. José was also a member of a Youth Action Council at the Michigan Science Museum where he engaged in monthly meetings/activity events and shared his opinion on the direction of the museum's programming. "The chances I do get to go there," he explained, "it is the funnest place I really go." But he maintained that those chances were rare. For the most part, "I really don't go anywhere except for Afterschool STEM Program and school. So I don't really do science anywhere else." Even still, José argued that his movement of knowledge across school, Afterschool STEM Program, and home delivered visible results: "It makes it easier to learn—makes it faster. I take all that knowledge and take it through."

José's pathway. José's pathway is more imaginative, because *he* has to be in order to survive pathway contexts that systems of racism and classism have worked to severely constrain as he seeks his desired STEM future (e.g., limiting his family's economic opportunities and therefore limiting his time with his top STEM pathway supporter). He wants to be known by the world as a "legendary" historical figure in engineering, desiring to build a career as a "master of an army of bionic gerbils," a genetic engineer, or a justice-seeking technological leader he called "hacker of hackers." Growing up with a close relationship with his mom and a much more distant relationship with other relatives, José has relied on his mom for support and guidance but also feels it important to build a pathway that can give back to her and give stature to the family name. His pathway is inspired by his mom, but there is a lack of people outside of his mom recognizing him or his pathway. As I show in this narrative, José is well aware of his own positioning in schooling and society, as a young Black male, but imagines powerful through-lines (e.g., historical impact, and justice-oriented partnership) that help him to push back against the various structures—real and symbolic—which make his desired pathway treacherous at times.

Pathway work-in-action: José as a history-community connector. José's desired pathway work included getting others around him to recognize him as a respected leader in his community and in STEM. I start his pathway narrative with the following vignette, because he explained that this was his first time doing a "higher level of engineering." He was proud of the highly technical elements of this work (elements recognizable to adults in power as traditional forms of STEM practice) and the clear and strong connection to what his friends and families wished for and needed (needs borne out of care, but also out of a materiality of structural constraint). It was also an event in which someone who wanted to be known as a historically important engineer sought to historically ground his engineering work.

José's STEM Club work began when he joined our arcade games unit as a sixth grader. He and a friend had decided to construct a modern version of a very old, not often played game called Puckett. Their game design called for wooden boards he cut with a power jigsaw, rubber bands they nailed into the wood, and a pile of plastic binder rings as pucks. They added to this list what they described as their secret weapon to take their design to the next level: an exciting combination of paint colors he and his project partner described as "pinkle." Pinkle, José and his teammate's favorite color, was a swirly splash of pink and purple that José proudly explained any gender should admire because, simply put, "It's pretty." José and his team member laughed and danced as they worked on their design and final prototype. As they sprayed their game with the neon hues they loved, it looked as if José was celebrating every moment of work with exuberance. His smile never stopped. By the time their project was complete, their team had a third member, a classmate and close friend of José's who told me that José "would not stop talking about Afterschool STEM Program" to him at school.

Jose was proud of how he worked on a "higher level of engineering" with his STEM-rich making work, which involved both designing-and-building and educating others about his designs. When the youth in his STEM program prepared to share their game designs with broader club membership, which meant over one hundred other youth would see his and his peers' work, he worked with his partner to create a lesson for younger peers about forces and motion that operated their Puckett game. They also developed a slideshow presentation on their process of investigating, designing, measuring, constructing, and testing games, which was meant to show others how they could do this too. Finally, they planned out rules of play, prize earning requirements, and preferred room flow, seeking to increase excitement around their game. José shared his awareness that other teams might attract more visitors than his team that day, as those other teams were seeking to "be trendy" by building already-popular games like skee-ball and bumper pool. He wanted to be sure that people valued his work too, and he wanted to play an active role in shifting the narrative on gaming.

For example, José explained to me, he was a public-facing "game historian" in that unit as well as a "game designer," because he had researched more old-fashioned games and was seeking to make one of them popular with children again. He discussed his younger community peers with respect, acknowledging them as important tastemakers full of intelligence and discerning opinions. He wanted to bring them an authentic experiential connection to the past, to help them enjoy play while also saving an important entertainment artifact from cultural extinction or erasure. He saw his game choice as a campaign to connect youth in his time to youth who came before. It was strategic action for social and cultural connection through time, fueled by STEM leaning and practice.

The day before their event, José invited his mother into our room to view his newly finished work and to share some constructive feedback as he made some final refinements to his design. This was her first time entering the room. I welcomed her, introduced her to the other adult program mentors in the room, and took the opportunity to share José's progress and the strengths he brought to the program (e.g., stating, "We love having José's engineering expertise here"). José beamed as he received the compliments and "good job, son" responses from his mom. We invited her to stay for a bit, to play a round of the game with him on the board.

As José's mom stayed and played with his game, I observed her leveraging this moment as an informal learning opportunity to help him test his project further, resulting in an important suggestion to make the surface more level. José took the suggestion seriously, and they stood together for a while examining the board and debating different materials to use to raise the surface. José settled on a few, large sheets of cardstock paper adhered on top of the slightly-slanted wooden platform for a smoother and more balanced play surface.

A couple of weeks after their event concluded, in a mid-year artifact interview, José discussed this modification suggested by his mom as a crucial optimization to his design. During this interview, he also requested adult help to search online for professionally made Puckett games on Amazon and Ebay, as his mother's birthday was coming up. A fellow mentor who was nearby assured him that his Puckett game would make her even happier than a store-bought version. A couple of days later, José convinced his partner to let him take the game home to surprise his mother.

Pathway work-in-action: STEM media activism. As noted earlier, Jose took the opportunity of the game showcase to teach his peers not only about how his game worked, but also the science and engineering behind how he built it. Jose built on this aspect of his pathway as he sought other opportunities to expand his own STEM knowledge and practices towards increasing opportunities to teach others. In this next vignette, I describe how José did this during his next major out-of-school project, one that shifted and expanded how he saw himself and his reach with his STEM engagement throughout his middle school years.

With his next afterschool project, José took action with STEM as a change agent and community leader for social justice. In this project, he and his friends developed a by-kids, for-kids YouTube channel to expand representation in education across race and age, in ways that restructured peer opportunities to see kids like him in ownership over their means of STEM education. José first came up with this project idea as a concrete way to speak back to power following the 2016 presidential election, and to support other youth in taking back some power over their own educational access, engagement, and opportunities for the future.

What is noteworthy are the various influences that propelled José's pathway work along these lines. For example, Trump's victory served as an urgent turning point for his work in Afterschool STEM Program that school year. As a member of Black and Latino communities, identities, family histories, and races, José understood the election result as a personal insult and as a disturbing threat to himself and the people he cared about the most. The impact of that event took many weeks for program members (and mentors) to process together. This shared processing continued throughout the school year as related political actions covered in news reports were making racism, classism, sexism, and other forms of dehumanization more visible and more urgently menacing. All youth participated in discussing what Trump's statements and priorities could mean for their friends and families, their communities, their educations, and their futures. According to José, none of this sounded good—or safe.

Within the context of daily life as middle school-aged youth, José and other youth had also shared awareness of and frustrations at continued resource disparities for STEM learning (e.g., including one local school's recent loss of "STEM academy" accreditation, necessitating a name change). Several youth in the program that school year had also heard the name Betsy DeVos frequently in the news, at school, or from parents or neighbors. Some shared an understanding that DeVos had played a negative role in their state's school policies, and they connected this understanding to critiques of how they saw their schools run poorly by adults.

José understood that adults in power were failing him and his generation, because they "don't care enough about kids or the community." More specifically, he understood that those people do not care about Black and Brown youth. He and two of his friends wanted to use their power to speak back against this failure. To do this, they developed and led alternative structures of engagement, innovation, and protection for people, environment, and learning. Youth-led solutions were the most logical solutions to systemic adult failures.

José's STEM-rich educational YouTube channel was an informed response to this political situation, and an opportunity to make the local expand in scale. He and two close friends began it immediately following election results, to expand informational access and enjoyment for youth without relying on adults who "don't care about kids like us," Youth of Color who had a passion for advancing their learning and who knew that they deserved the resources to support it. José's school had frustrated him and had never fully recognized him for the high-tech expert he knew he was. Trump's cabinet member, a Michigan school leader, was implicated in that educational disrespect he had lived through. School and the adults who structured it were not fulfilling their responsibilities to "youth innovators like us," so he and his team members designed an alternative learning space. This one would be designed "by kids, for kids" with respect for diverse youth ownership over STEM learning as a top goal and driver. José knew that "kids who look like us" could do it because he knew they had expertise to share: "We are all experts on YouTube because we watch it all the time and know what kids like. We are experts in science because of the time we spend in [Afterschool STEM Program]."

Their channel contained dozens of videos documenting their intellectually complex ideas, processes, and products of STEM engagement. Each video was written, directed, and produced by youth. Playlists also included a collection of award-winning public service announcements created by program members from earlier years to educate the city on environmental conservation and green energy issues. When viewers visited their channel, a 44 second action movie-style trailer greeted them. Fast-paced, thumping beats heralded three "fun and hardworking green energy experts" posing with the words "3 Engineers… These kids know their stuff… and want to share it with the world." Below that video, comments started appearing: "You guys are making a difference - don't quit - you're going to change the world."; "So proud of all of you!!! Break that glass ceiling!!!"; and "ayeeeeee" (another way of saying "yeah!").

José had gained an online presence as a leader and creator through civic engagement grounded in critical agency against educational injustice. As he and his team members explained in presentation materials, "Most educational or DIY videos on YouTube are not made by kids who look like us or care about the things we do." He had taken a stand with STEM digital engagement in a team of trusted friends that became a coalition for educational justice. This effort continued with new STEM-rich, educational videos uploaded every month. José's digital technology project expanded peer access to ways of being and learning in the power-mediated and systemically problematic world of STEM.

Figure 12: José (left) with YouTube channel co-designers

In Spring 2017, José joined his group and six other project groups in representing Afterschool STEM Program at a regional entrepreneurial showcase for "youth startups." His team took first place in the category of "green technology design." An excerpt from the "business plan" they submitted there is included below:

> We're concerned about education in this country. We are concerned because of the previous political election and what it could mean for us as children who want to learn. … Science and engineering can help the earth if kids use it for good. We want to help the world by sharing science and engineering knowledge with other kids on the internet… Anybody that feels like they're not learning enough science, math, or engineering in school and anyone who doesn't want a boring grown-up to tell them what to do can visit our channel and learn from us... This is for all kids… there is always more stuff to learn, and we can help you learn. We are the teachers…We are kids talking about science and math and engineering in fun ways… A lot of people… don't learn enough in school about science, engineering, math, or making things like we do in our makerspace after

school. We want to change that so people can learn more without having to take expensive classes.

As they argued in the quote above, José and his friends wanted their showcase audience to identify them as experts who were making a legendary impact in the world. They were youth who "knew their stuff," who saw an injustice in the world, and who were taking action to change things for the better.

Throughout these efforts, José's mom took on important roles as cheerleader, publicity agent, chaperone, and advice-giver. For example, following her first visit to Afterschool STEM Program, she stayed in contact with me by text more frequently. This led to more direct program involvement and parent-teacher partnership, including carpooling with STEM Club mentors to help transport presentation laptops and poster boards to the youth startup showcase later that school year. She also surprised José by taking off work that day and staying for the entire event as a chaperone and cheering section for his entire project group. Finally, she was one of the group's first YouTube followers, and she enlisted his older brother's assistance in sharing links with his social network as well as her coworkers and relatives.

Pathway work-in-action: STEM teaching mentor. José also consistently sought opportunities to gain leadership and recognition for his pathway efforts within and across his learning environments. As he moved across space and time, he leveraged action in one space to expand his recognition in additional spaces. For example, he requested teen and adult assistance in more explicitly scaffolding his development as a community leader in STEM. Throughout his membership in the Afterschool STEM Program, he had observed teen/adult collaborations that positioned teen mentors with power across our connected spaces. In the summer after his sixth grade year, in recognition of his joyful and committed engagement in our two-week-long summer camp at the Michigan Community Center, we invited him to also join us for a five-day STEM/maker camp we were partnering to lead at the local Michigan Science Museum later that month. In order to keep camp numbers small, it was only open to members of the Center's Youth Action Council, a new youth leadership group that advised the science center on design and programming decisions. Jose was one of a handful of youth we had recommended to invite into Council membership for the following school year, so we decided that the summer camp could serve as a helpful first introduction to the Council as well as an extended opportunity for summer STEM engagement.

At camp, youth were tasked with completing small-scale engineering design projects to solve specific local problems using materials available in the Michigan Science Museum's makerspace. Fall and Samuel, Afterschool STEM Program teen mentors, were not surprised by José's request to join them; they knew José looked up to them. They accepted his request to join their table and help them come up with ideas. After one full day of designing a mini-trashcan to snap under student desks, the three all turned their attention to a fourth camper they knew from the Afterschool STEM Program, Wolf. Wolf had embarked on a solo project at the table next to them: a keepsake box camouflaged with a hardcover book facade to elude his nosy siblings. Samuel, Fall, and José were immediately curious. Their interest hit its peak when Wolf wondered aloud how to slice through hardcover books, and a staff member announced that Wolf could bring books to their exhibit workshop (where adults constructed exhibits with CNC lasers, routers, box saws, band saws, and other irresistible power tools). That afternoon, I purchased enough 25 cent thrift store hardcover books to make at least four keepsake boxes, as I could surmise the likelihood of a certain three campers deciding to switch projects last-minute.

As Wolf was escorted to the workshop the following morning, the other three immediately followed. The workshop manager handed out safety goggles, and all four took turns holding the chop saw's handle and guiding it down, watching with eyes wide as it sliced cleanly through book layers. Back in the makerspace, they dived into four different keepsake box designs. The four joked and laughed together as they screwed, hammered, and painted. José integrated a power circuit in his design, boring small holes in the box's side and pulling a wire through. He borrowed my phone to take several selfies and a few videos featuring his LED light-up box, asking me to text copies to him and his mom.

Figure 13: Left to right: the camp group; José and his design; José with Samuel and Fall

In the beginning of seventh grade, José shared an intention to be an Afterschool STEM Program mentor during high school, "just like Fall and Samuel." After one session later that fall, he asked me for permission to start practicing as a mentor immediately. I wondered with him about the potential for inequitable power dynamics if we gave a seventh grader the public title of mentor to his older eighth grade peers in the program. I acknowledged his desire to speed up a promotion process, and we brainstormed together what a satisfactory solution could look like, including opportunities for mentoring younger peers. At the beginning of the very next session, however, he stood next to Fall as his peers all took seats at our discussion table. One of his friends asked him to join, but he answered that he was now a "STEM Program mentor, like Samuel and Fall." I attempted to pivot his statement without publicly denouncing his positioning work in the room, announcing, "Yes, José is going to be a mentor-in-training."

That day, he followed Fall around the room and sat next to her when she helped an app design group. I visited and asked him if he could assist that group by hearing their updates and contributing some ideas of his own. This was an action he had performed as a peer work partner—the only difference was the perspective with which he performed the action. But this pivot to mentor-in-training was meaningful and consequential to José. That different type of engagement led to more consistent attendance throughout the next few months.

Structural flexibility opened an avenue for José to explore his developing identity-in-practice as a legitimate leader in a power-mediated space. Acknowledging and making space for this leadership development was a challenge that he presented to me as necessary for respecting the ways in which he wanted to be and become in our shared space. Opening up that pocket of power supported Jose's development along his desired STEM pathway, in that it led to him designing what would become the "Mentors in Training (MIT) Program." This naming was intentional, as José explained that he was worthy of recognition as a tech genius in equal standing to scholars at Ivy League technical programs. By the end of that school year, he had welcomed two friends into the program (Jazmyn and Wolf) and had directed them in a promotional video introducing Afterschool STEM Program members to his creation.

Figure 14: Left to right, Wolf, Jazmyn, and José in José's MIT Program video

By expanding boundaries of practice and ways of being in our space, Jose worked to gain recognition for his desires to grow and change in the program. Instead of being silenced or pushed until the point of snapping as he had experienced in other STEM spaces, he knew he deserved to be granted access to higher-power positionings and possibilities.

Pathway resources: the importance of the people around him. Similar to Jazmyn, when I asked José to name his most important STEM pathway resource, he simply announced, "people, and how they help me." As we explored together what he meant, however, we uncovered layers of how different people in José's life structured his pathway efforts in different ways. Personal and institutional relationships shifted, in both positive and negative ways, his sociocultural interactions with and views of the structures around him as he sought his desired STEM pathway.

Partners as connectors. The people who José deemed helpful supported him in connecting STEM spaces and places of his life, "like how my mom helps me with homework… And how I take knowledge from STEM Club and bring it to school, and how I also take knowledge from school and bring it to Afterschool STEM Program." José credited his school's institutional partnership with the local Michigan Science Museum as what brought him to the Afterschool STEM Program, because it piqued his interest in out-of-school science learning. That program then connected him to further levels of exciting STEM engagement and opportunity. He hoped to continue making new connections until the day when he could "surpass all others, [like] Bill Gates, Stephen Hawking, Albert Einstein. They are all really smart people. When I grow older, I'm going to be smarter." He credited the Afterschool STEM Program as full of people-type resources that could help him "get there," including teachers who "listen and understand what you're trying to say—then get up and teach you to help you learn more." This echoed the literature on “nerd networks” mediating the sharing of technocultural resources through collaborative projects, a traditionally inequitable social structuring that José found an alternative way to tap into through his afterschool program’s STEM engagement community (Eglash, 2002, p 50).

Partners as friends. He included peers as helpful STEM pathway resources, especially close friends. “You can't just have good partnerships with people you don't get along with,” he explained, and partnerships in work were extremely important to José. For example, he emphasized the importance of looking for and embracing “other people's ideas to help out with mine.” This, to him, was the heart of teamwork:

> Because everyone's helping… everyone gets credit. Everyone is appreciated for working. It's even and it's fair. It's important to me because it's fair. All you need is smarts, education, hard work, and teamwork. And people that have your back.

José maintained, for example, that he wouldn't have been able to come up with some of his YouTube ideas by himself. He insisted in sharing credit for that project, because “it was some my idea, but *we* made it.”

Powerful others as conditional resources. People and the support they offered populated José’s list of top moments with STEM, along with “learning, dealing with, working, and doing” STEM including chemistry, green energy, and engineering. People taking away support populated José’s worst moments, which all involved “getting in trouble,” in different forms, with more powerful others. José considered getting in trouble to be his most dangerous pathway roadblock, because he understood reputations as mediating the people-to-people interactions that could either expand or constrain access to desired resources and opportunities. This was part of what José was referring to when he stated in his portfolio’s introduction page: “Watch out for the twists and turns; some of them might be dangerous." He believed that success meant striving to be the best version of a human he could be, so that other people would recognize his efforts and offer him the support and acknowledgement he desired. He credited this idea to his mother's teachings: "She raised me to be the best. *I want to be the very best // Like no one ever was // dun dun dun* [sang Pokémon theme song lyrics, in melody]" (Siegler & Loeffler, 1999).

Powerful others as supporters. José's STEM pathway work involved following the guidance of "helpers" who supported him in "mastering" what he was learning so he could take what he learned from one experience to another across spaces and over time. This person-supported movement of learning across space and time would help José "move on quicker" towards his goals. He pushed for continued expansion of community support structures, including people reaching across a wide variety of capacities, perspectives, and skills who could support his efforts. In discussing STEM mentors in his out-of-school STEM engagement spaces, for example, he cultivated a collection of relationships that assisted him differently: "Samuel, he breaks it down… Fall forces you to learn in a mean but nice way… Day is just really fun which makes you want to learn more… Angie's serious which helps you out." When I asked what other types of mentors, in a perfect version of life, would help him reach what he described as his envisioned "mastery" level of STEM engagement, he explained:

> I still want more [types of mentors]… even more… Like in college I could be in a dorm, and they could be a student too, always next door, always helping with homework and stuff if I'm having trouble. They can have my back.

José wanted all the support he could get. As he continued to build his STEM pathway, he planned to continue surrounding and strengthening it from all sides with a spectrum of pathway supporters. For as long as possible, though, he planned to stick closest to his most important supporter, his mom: “She helps me with everything, and helps me to prepare for the future.”

This reaching for ever-expanding support structures across time into the future mirrored his work to expand educational supports for other youth. “We're in the process of something great,” he acknowledged about his YouTube channel to broaden access to rich and meaningful engagement in STEM learning and practice. Even with his mom, he sought a reciprocal relationship of impact: “I've helped my mom and my mom's helped me. She said I help her by making her proud.”

How José projected his pathway efforts across scales. José’s desired future in engineering centered on achieving acclaim in the eyes of others around the world for accomplishing unexpected technological feats. Knowing that he had already started on this pathway was an encouragement, wanted his pathway portfolio to demonstrate that forward movement. José argued about this research, “I think it says that I've really come far as a hard worker and I've achieved a lot. I'm good at learning and I know that I can grow even more. I'm going to be an awesome scientist or engineer.” He added that he considers himself a scientist and engineer currently, but in the future, “I’m going to be a more awesome one.” There is a lot that José hopes to accomplish with STEM learning and practice in the future, but he also acknowledged the importance of incremental movement and growth in his pathway (and focusing on one challenge at a time), because: “Isn’t that how success awaits?”

To José, the point of telling other people about his pathway is to help them learn from his experiences so that they might be inspired to make the right decisions and “take the right paths” for themselves. One of these decisions was how to treat others. He wanted to represent teamwork prominently in his portfolio materials, because he argued that science cannot happen without it:

"In science, there is more than one person doing the job. There's always teamwork included in it." He referenced the aphorism that if you fail, you must "try, try again," clarifying that "the two *tries* means including other people." He prioritized kindness, not just because it made people feel good but because the more good he shared, "the more help I'll get and the better my team will do. People will want to work with me more. If you do more good stuff, people will help you more. And that's good karma."

Looking ahead, José discussed the possibility that the exposure from this project could lead to some new helpful relationships for him in his future. With this in mind, José wanted people to hear about him and think: "That guy's so cool because he's a kid and he's doing stuff like that." He wanted recognition for all of the following:

- As "a good karma bringer guy,"
- someone who cares,
- who is not afraid to "face challenges,"
- who "would do anything to protect my fellow peeps,"
- a "born leader"
- who "stands out,"
- a hardworking student with "high goals that I need to achieve," and
- a young person who is deserving of a positive reputation, college path, and career.

He hoped this study would draw a large audience because he wanted to inspire awe in other people. This was connected to his desire to be well-respected by the world, but it was also connected to his belief that there is no success alone, and that learning is meant to be moved and shared. As he explained:

> I would want everybody to see it because I want everyone to know who I am. I'm a legend. I'll be a legend. Like the song. *If I die, if I die, if I die, I'm a legend!* [Sang modified lyrics to Drake's "Legend," in melody] (PARTYNEXTDOOR et al., 2015). Everybody will know my name. I'll be like Alexander Hamilton. Everybody knows his name. And they all know Bill Gates, and they all know Albert Einstein. I'll be famous and I'll be an inspiration. An inspiration to kids so they'll get up off their butts and do stuff. Big stuff. I want to affect everyone.

How José imagined his pathway's future. When thinking about his future, José's most important goal was his desire to be well-known in the world. He saw STEM as one way towards that goal. He hoped to one day create or discover something, arguing that some of the smartest people in the world discovered new things which made them immortal through sustained public recognition by others. He explained that engineering could be one way to accomplish this, because in engineering, "usually you're either making something complex or inventing something." The work of engineers, for José, was not only about improving things that are "already made and existing." This was part of it, but not the part that would necessarily get one "known" by others. In engineering, he clarified with a stoic seriousness, "you innovate, too."

Within the engineering field, José seriously considered becoming "a bionics person." He described his interest in combining biological systems and methods with engineering technology as stemming from his love of Japanese cartoons and his imaginative daydreams about making bionic and genetically modified animals. "I could be the master of my own bionic army of gerbils," he explained. "They will be very cute but deadly to my enemies, all the people who wronged me in life." These enemies include a stranger online who hacked his friend's Roblox account and took 9,000 "Robucks." José explained that in time, it will become "very easy to track him down since in the future I will be a computer genius." His description of what his computer genius identity would entail involved multiple layers of intersecting skills, repertoires of practices, experiences, and ways of being that he had cultivated across the spaces in which he conducted his daily STEM work:

> I will hack to find the hackers. I'm going to probably be one of those CSI or FBI agents that can track down these hacker people for doing illegal stuff, any kind of hacking, for bad use. I will be the world's greatest hacker-tracker. I'm going to make my own super computer using solar power because my office is going to be made of indestructible glass and my solar powered computer will be super. It will not have any carbon footprint like carbon dioxide produced which can cause pollution. My office is going to have a lot of tech and I'll be a successful worker to probably own a penthouse and my office will be in that. I will have a lot of trees around it to absorb carbon dioxide and release oxygen.

José discussed his desire to do well in science and math classes in order to open up more opportunities for himself and his dreams: "It's important to me so I can impress my mom and stretch out for success." School grades quantified how well he was following such guidance, so if he could achieve a 4.0 grade point average, he would know that he was "the best" and on his way to becoming "the very best." Becoming the very best would mean that José would "get scholarships and stuff, and it'll progress me more." Being a bionic surgeon would probably also require admittance to a top medical program: "That means get all A's and study hard, pupper!" This first required raising his "failing grade in math." His mother was saving money for tutoring. "I can't get really bad grades or I'll lose my scholarship for college," he explained. José was actually not sure about the terms of his scholarship, "but just in case." The scholarship program, a popular one in his city that was sponsored by a retired NBA celebrity who grew up in their city, necessitated him staying in his school district through high school and enrolling for two years in his town’s community college, before transferring for another two years tuition-free at the nearby public university. Youth were accepted into the program if they made a minimum grade point average throughout their sixth-grade year. Although it limited his options for higher education, “You get free dorms and everything,” so to him, it was a tradeoff he was willing to make.

José’s desire to become more “known” through engineering success in the future was connected to his devotion to his family. In informal conversations with me, he shared a sharp awareness of some important ways in which his family was positioned by racist and classist systemic forces, and some ways in which different family members had positioned him. He considered himself a strong candidate for achieving honor and capital that he could share with his family:

> I want to be known as someone that did something no one had done before. I have not been known a lot. I want to be known as someone that will change the world… I want to find something that's helpful and useful. It'll be named after me. I'll put it down on my family's name. Not a lot of stuff is in my family's name. So when I die… I'll die as one of the best. As one of the best people that were alive… I just want to have something for my family to remember me for. Like, I know they'll remember me, but I want some more for them to remember me about.

José was on his way towards this future, and he recognized growth in his pathway with STEM throughout time:

> Because at age 5 I was just playing around with science. Right now I'm tinkering with it. I'm making it more complex. I'm just learning way more about it. And in the future I'm going to be mostly mastered in it. Well "mastered" in it, quotation marks. I'll be way

> better at making it and discovering more about it. Right now I'm learning a lot about it and tinkering with it. At 5 I was just playing around.

In narrating this pathway of growth to me, José's storytelling cycled forward and backward, weaving a pathway of experiences, relationships, resources, and power across space that stretched through dimensions. He was actively working to cultivate the support he knew he would need in order to continue his determined climb upwards. People would be the key to him "getting there."

Sincere

Sincere is a popular social leader. During an interview for this study, he described himself as "a leader" who "can make a difference." He valued personal independence for himself and a communal sense of wellness across his community; he saw building a pathway with STEM as a strategy for achieving these goals. A central campaign of his pathway work involved leveraging his STEM engagement and his peers' respect for him towards organizing support for younger children in his community, a commitment connected to his close relationship with his little sister "that I love very much and I take care of and protect." He navigated STEM learning and practice through complicated and inequitable structures across his life as he built his pathway towards a desired future with architectural engineering.

"I feel like I can not necessarily change the world, but I can make a difference," Sincere explained to me, as we were discussing what we thought were some themes in this narrative and in his life. "I want to do that because I want to, not necessarily prove everyone wrong, but I want to show people that I can actually do something. And that my life had purpose." Many people in Sincere's life have attempted to label and control his actions and abilities. In first grade, for example, Sincere experienced what too many young, Black boys like him have gone through: his

White teacher labeled him a disruptive problem that needed solving. “She told my mom that I might have something wrong with my brain because I had too much energy and I might need to go on medicine,” he explained. He recalled vividly how this had felt as a six-year-old. His ways of being and moving in his learning space had been judged as deficits (Solorzano, 1997). A power-holder charged with his care had told him his brain was not OK, and recommended drug-enforced obedience. This was a lesson he carried with him over time and across space, and it influenced how he saw the world around him. He learned to move in that complicated and inequitable world knowing that he was a good, capable, and intelligent person, but also knowing that he would need to defend himself by proving it to others with more power than him (Tenenbaum & Ruck, 2007; McKown & Weinstein, 2008). “I feel like I have already,” he added. Still, “I want to continue doing that in the future… I want to show people.”

Sincere became a social strategist in order to navigate against a current of dangerous structures. Seeking and leveraging opportunities within tensions of power became a survival strategy for him, as did recognizing who was an ally and who was an obstacle: “Sometimes people just want to think what they want to think, but other times they will be more open. You have to be able to persuade people sometimes” Seven years later, he talked with me about using this study as an opportunity to speak back to judgments like that. He wanted to tell the world his story, his way. “I want to like tell people that that does not matter to me. I want to prove that’s not right. Too much energy doesn’t matter to me. I can put the energy to something good.”

Sincere had learned ways to be himself while still navigating structures of power: “I’m not a nerd, but not average either. A goofy kid that still gets the job done efficiently and well.” His mother moved him to a different school for his middle grade years, one with uniforms and a bigger budget. He acknowledged a collection of differing contextual shifts that this resource-level brought, including classmates with more social capital privileges, and more stressful academic competition. He also observed more resources to support him in “being more challenged” in academic tasks. He explained that at that new school, his most important resource was his science teacher, mostly because “we talk a lot.” For example, when he narrated receiving second place at his seventh-grade science fair, he went into much greater detail during the part of the story where his teacher pulled him aside to recognize him and his project personally.

Sincere was well-liked, with many friends in school and at the Michigan Community Center. His popularity sometimes got him in trouble, as he enjoyed “playing around” and telling jokes even when adults requested quiet seriousness. But in those moments, he displayed expert skill in negotiating with adults in power (e.g. me) to “give [him] a break” and “see it [his] way.” In one example, about a month into his first year in our Afterschool STEM Program (his sixth-grade year), I had noticed his focus wavering. For a few sessions in a row, he had been walking around the room telling jokes and chatting, but he had not gotten much work done on his project. He also frequently left early or skipped sessions entirely, claiming that his ride was there to pick him up (and I would see him an hour later, running in the halls with friends). I asked him for help in brainstorming a more sustainable relationship together. He explained that he was committed to building his STEM skills and “doing cool things” with us, but he needed more outlets afterschool to “let out energy,” especially when it had been “a bad day at school.” He successfully persuaded me and my fellow program mentors that the most reasonable solution involved arriving at the start of our program to participate in snack time, then depending on the Center’s gym schedule and how his day was going, he would leave for a half hour to play basketball whenever he felt he needed that break. After that compromise, he rarely missed a program session.

Sincere's pathway. Sincere seeks to gain autonomy through his STEM pathway. He is trying to become a young man but in ways that are both socially and professionally acceptable so that he can be recognized in ways he wants to be. His pathway involves gaining freedom and power through STEM learning and practice, for him as well as for his younger sister. He understands that accomplishing this desired STEM pathway work will require continued strategy to navigate the constraining structures that seek to control him and other youth.

During his seventh-grade year, I asked Sincere if he wanted to participate in this research project, as a leader who often talked about a future in engineering. He began his portfolio by writing: "I am a kid that likes engineering and technology and a kid that has a dream to be an engineer." He added that doing informal STEM pushed that dream forward: "Everyday I find out something new… It kind of helps me be an architectural engineer." Architectural engineering was a field where he felt he could turn his imagination into physical realization, and "get $100,000 a year for doing it." It was also where he could "be my own boss," acknowledging his dislike for "listening to other people's orders when I'm working instead of my own." He connected this future thinking to his aunt's stories as an electrical architect: "They have to listen to her. She can always do her own idea." He also shared his mom's advice that if you work for someone else, "they're in control." Sincere used his family's stories as resources helping him construct the life pathway he knows that he wants. This is deliberate, self-aware futuring work:

> It's important to me... If I was my own boss, then I would not have to listen to other people's orders. I would listen to myself. That would make me more comfortable… I'd know that even if something isn't right, I can fix it without getting in trouble.

Sincere understood STEM as learning areas that "can help me get there because I will know what to do…there is a lot of math in engineering and a lot of technology and science in architecture.

And there's a lot of engineering in engineering!" Sincere was also passionate about strategy-heavy games like basketball, Minecraft, Roblox, Tomb Raider, and Assassin's Creed. Sincere explained that strategy games "help in everyday life" because "that's how I go through life."

He was also passionate about working towards justice on a local level. "I think somebody who has authority or power should make a difference for people that are living in their city," he explained. "Instead of just sitting back and thinking of myself and things I could do, it's more so helping the community and the city." Sincere was a risk-taker and problem-solver, and he wanted to learn how to use those skills in science and engineering to help himself and others: "And I like working hard."

Pathway work-in-action: strategic engineering for more equitable leisure. Sincere sought a future for himself that included more independence to enjoy his life without the constraints placed upon him by more powerful others. As he worked towards that future, he used his STEM engagement to help others access a similar type of agency, especially younger children whom he recognized as having less power than him. In the following vignette, I trace one example of Sincere's strategic efforts to do this.

During Sincere's first year with our program, we introduced an arcade games design unit to explore structural engineering design, play with ideas about force and motion, and leverage member interest in using woodshop power tools in the makerspace. When his group decided to design a "bumper pool" table, Sincere argued to scale it down in size so that younger children could play it at the club without worrying about competing with older kids for use of the full-size tables. To a lesser extent, the design addressed the physical issue of shorter players being slowed down by taller table height issues, but Sincere emphasized the "not right" social dynamics at play in the club's all-ages games room where his then-sixth grade peers out-ranked younger club members who suffered long waits for turns. He explained, “Some people just like need help… Some people get bullied and they don't know what's going on.”

Bumper pool was an extremely popular game at the Michigan Community Center. Exhibiting high-level bumper pool playing skills was a cool currency in the club’s peer culture, and younger club members often watched older members compete. Sometimes they played as well, but the decision to play required courage to confront older players who controlled play structure and table use. This control occurred through implicit social structures of masculinity performance and athletic elitism that often left younger, smaller, and/or female players at a disadvantage. Player hierarchy was also structured more explicitly in daily bracket competitions that limited more open and less judgmental opportunities to learn and get better. Afterschool STEM members were well-versed in these structures of play, and some excelled within them (e.g., Sincere won many tournaments, and Keke had acted as league manager, directing players and writing winner names on a clipboard).

Sincere and many of his friends could navigate these structures of play easily, but the same could not be said for people like his younger sister and her peers. He wanted his project group to create a bumper pool table that would be free from these restrictions. If he could create a table short enough that it would be less attractive or more difficult for the older and taller kids to play on it, the table might escape colonization by the all-ages competition. He wanted to enhance structures of play for all ages by reducing competition for the children he saw as more vulnerable within the uneven power dynamics he observed in the game room. This was a project where he could use engineering to help others, which he argued made the work more enjoyable for him:

> There's a lot of architects but not all of 'em are in good heart or in good will of what they're doing because some people just wanna do it for the money. I would enjoy the money… but it's also good to feel good about what you're doing with it or what you're accomplishing.

Sincere and his group designed the table to be not only shorter but smaller in tabletop area and without a dampening under-pad, which then raised the need for a different ball design. They needed a ball that wouldn't be as dangerous for younger children as a hard and heavy pool ball would be, particularly because they discovered in their test runs that a smaller tabletop with less resistance could increase the risk of balls shooting off the table from overeager players (even with their bumpers and walls). They tested different balls with younger users in mind, as players with less experience and finesse who would need easy-to-handle equipment while they learned the game. A sand-filled squeezable stress ball's speed suffered from too much mass and friction; a foam-filled dog toy ball and a plastic ping pong ball had great surface texture and bounce but were both too light to remain on the table for long; a tennis ball wasn't perfect but matched "close enough" for their prototype's intersecting design, budget, and time frame needs. "I took my time on it to make sure it was good enough to play and make sure it was fun," Sincere explained later, in an interview about his group's design process. "It was kinda hard to build because we had to make sure all the steps were right because if it was wrong, we'd have to take the whole thing apart just to fix the one thing."

About a week later, Sincere's leadership skills were tested in a critical moment of decision-making and action with STEM learning and practice. His teammates were absent, and he had a new design problem: the tennis ball was just a tiny bit too large to work with their table's goal circumference, and its fuzzy surface still wasn't providing a satisfying enough level of resistance for harder hits. Meanwhile, the group had only 2 more sessions until Afterschool STEM's event to unveil a collection of youth-made games and invite younger children into the room to play them. As he explained to me, ease of use was paramount, and this was no time to compromise on product integrity. So, Sincere came up with a quick solution: with a power jigsaw, he cut bigger goalie holes, measured for more comfortable use with tennis balls. Then, he increased table resistance by covering their wooden table top with a recycled flannel-type fabric.

Figure 15: Sincere's bumper pool table

Sincere's in-the-moment decision to expand goal size, add fabric, and reconstruct the top aesthetic design was skilled strategy. They had already spent much time painting soccer field-type lines on their table and hot gluing clay-filled paper cup bumpers, so he knew he'd have to redo a lot of that detailing work on top of the new surface. Any lines he cut through or covered would need to be redrawn/re-painted with at least the same level of aesthetic quality, as "I wanted be proud of what I made." His ability to take on this challenge alone spoke to his self-confidence built over time and across space as he took on prior challenges of varying degrees. For example, he had made smaller design decisions as team representative earlier in the process, as this was not the first day he worked in our space with a work partner absent. He had also experienced success in arguing with material evidence for different component inclusion and in convincing team members of his argument's validity (e.g., the original design for painting the table was his idea).

This in-the-moment strategizing was made possible by several layers of experience intersecting over time. In and outside of his makerspace program, Sincere had developed his knowledge and leveraging of available resources, his emotional trust in his group members that this choice would not backfire on him socially, and his awareness of his own power to take action towards his group's desired goals. It was fueled by his dedication to making a product for his younger community members that was up to the quality he felt they deserved.

Finally, this engineering decision-making was leadership to deliver on his promises to his community's children. He explained later in an artifact interview about that project, "It felt good cause I felt I did something useful. I did something that would be useful for a long time." In the actions he took as a creator with STEM, Sincere produced an outcome that he could leverage as proof of his legitimacy to make change happen for his community with science and engineering knowledge and practice. And, importantly, his in-the-moment actions produced observable outcomes that carried a sense of longevity, adding to his movement through scales of time.

Pathway work-in-action: strategic design for shared independence. As he demonstrated in the above vignette, Sincere cared about building things that helped others. He wanted to use his engineering expertise for good, and he drew from his own lived experiences and personal desires in the world (e.g., desires for more agency) to make this engineering effort more complex.

Sincere's next project in Afterschool STEM leveraged his respect and admiration as a project team leader to make a wider range of healthy food options available to him and his peers after school. Halfway through his sixth-grade year, after the arcade game unit, both youth and adults were struggling to understand and address what the 2016 election results might mean for their lives, their families and friends, their learning, and their opportunities to pursue their dreams. So Afterschool STEM members decided in a youth-adult co-planning session that for our next unit, a focus on “technological design for social justice” could help scaffold efforts to address new politically informed social and community concerns with science and engineering learning and practice.

As a first step, Afterschool STEM youth created a community ethnographic survey to ask people in their schools and neighborhoods what the most pressing social injustices were, in their experience and perspectives. In the following weeks, they worked together to analyze and interpret the data they had collected and to define and bound specific problem spaces to be addressed with science and engineering knowledge and practice. To their question of “What challenges related to our community do you think are most important (select 2)”, the second-most chosen answer option, at 35 percent, was “Need better access to affordable healthy foods.”

Open-ended responses to follow-up questions mentioned several different layers and sides to the problem of accessing affordable healthy food. Some were most concerned with the economics of the issue, complaining that, “Healthy food cost too much it's cheaper to buy junk food then healthy food.” Some respondents wrote on the public health implications and consequences of different types of food consumption: “Some people die for not eating healthy”; “People need to know about why it is important to eat healthy.” Others critiqued a lack of options available in the neighborhood and in the afterschool organization itself: “more small stores that sell produce and not just chips/gum”; and “More healthy options to the canteen.” While the Michigan Community Center served a free after school meal each day, the canteen was the term for the club’s second food option run by Granny, the club’s kitchen manager. The canteen was a popular snack counter that opened in the club lobby when the kitchen shut down for the night. For a few quarters, club members could purchase hot dogs, nachos, candy, and other fun junk food-type snacks.

During these weeks, a parallel thread of concern had occurred in Sincere's life, that ended up informing and influencing he how understood and took action on the problems he had researched. Sincere had gotten into trouble with adults several different times for what had become an ongoing problem in his middle school life. As a preteen yearning for more independence and mobility, Sincere had been caught several times walking the eight or so blocks from his school to the Michigan Community Center building, instead of waiting for the school bus or the Michigan Community Center van to pick him up. His mom had begun calling my cell phone and the club's front office to ask where he was after school and if he had gotten there safely. He had been reprimanded several times. One of his reasons for continuing to break his mother's rule, he explained, was about his desire for personal freedom to move about on the sidewalks of his own community. He wanted the opportunity to gain a sense of ownership over his own mobility without engendering fear in the mind of adults who held power over him.

Sincere wanted more independence, and he requested to make this situation an engineering design problem that he could solve in our program. His initial design idea involved organizing a network of senior citizen sidewalk escorts between neighborhood schools and the Center. He engaged in a second round of community ethnographic methods with his peers, this time positioning himself as a community representative to be interviewed by his fellow youth STEM investigators. Through this exercise, peers helped him uncover another layer to his problem space: across the street from his school (a half-mile walk from the Center) was a mini-mart that sold junk food snacks he preferred to the Center's canteen offerings. If he had "better snack options" at the Center, he would feel less tempted to "run away" to the store. With this in mind, he connected his own case to the data he and his peers had collected on making "healthy food" more accessible. Sincere had also gained a solid foundation in gardening and plant science from watching and helping his mom with the vegetable garden she proudly kept up in their yard. He explained that this project could be an opportunity to get involved in a large community issue that could tap into his expertise with growing food and also solve his problem of snack boredom. He formed a group to design a greenhouse.

As his group began their research on the issue of healthy food inaccessibility, another group was already using the term "library desert" to describe the Community Center's neighborhood in their investigation around little free libraries. Program mentors mentioned that Sincere might look at his experience as a youth-specific "food desert" in the neighborhood. There were fresh produce-selling grocery stores one mile north and one mile south of the Center, but they both sat on a high-traffic road that was unsafe for youth to walk next to alone. The only walkable option was the mini-mart, echoing literature on the systemic racism of low-income communities of Color lacking walkable access to food options healthier than mini-marts and liquor stores (Alkon & Agyeman, 2011). Sincere and his group spent the next afternoon watched YouTube videos with the term "food desert" as well as videos with the terms "community garden" and "DIY greenhouse." They continued to further complicate their problem space together as they explored inequities of different possible solutions. For example, in his group's resulting PowerPoint of their findings, they argued

> Healthy food costs MORE than junk food… Other greenhouses cost money to join as a member of a CSA (community supported agriculture) group… and kids we know don't

> have money for that… Our greenhouse will be free and joyful… The goal for the greenhouse is to make a point that everyone matters.

As Sincere and his friends gained more complex understandings of their community's food landscape, they turned their learning into calls to action (e.g., as the quote above demonstrates). They wanted to engineer a solution to their personal needs that would also benefit other youth.

To begin their solution design process, Sincere came up with a list of snacks he would like (Takis chips and nachos made the top of the list). Then, he brainstormed with his group what produce they would need to plant in order to make those snacks. For example, they loved the nachos sold by the Center, but they wanted more topping variety. They decided to prioritize salsa as their goal and listed tomatoes, peppers, onions, and herbs they would need to grow. They conducted research on how much space, light, and water each different plant would need to produce their desired ingredients. Then they presented Program mentors with a list of items to purchase, including seeds, soils, and—because Sincere wanted to use the power jigsaw again—lumber cuts and wood glue so they could build their own wooden planter boxes.

With a very large bag of potting soil sitting against a wall and waiting to be poured, Sincere invited any available peers to help him measured, cut, and construct deep wooden planters. Arriving the next day to see his first planter completely glue-dry and ready to be used, Sincere removed clamp supports, slammed the planter on the closest table, filled it with soil mixture, and excitedly poured out several different types of seeds in an unorganized, celebratory sprinkle. Then he laughed with friends at what he had just done, remembering he had planned to move to the next step more carefully. Several peers joined him in sticking their hands in the dirt and scooping up or digging out as many seeds as they could find. The seed containers that still had a few seeds left made re-identification easy. For the others, we did some Google Image searching together. When he was ready for a second planting attempt, Sincere used the seed containers as labels demarcating each row of now-carefully planted seeds, with a one-inch space between each. As seeds began to sprout and grow into seedlings, he kept the plants in our makerspace underneath two windows to protect them from the early-spring cold.

Sincere's group members changed over time as he continued to show up at our makerspace door with more friends as project assistants (e.g., asking me, "Can he help me today?" and then turning to his friend with an inviting "c'mon!"). This included one young man who was not yet an Afterschool STEM member but decided to join the program in order to continue working on the project. By the time he entered his greenhouse group design to a local entrepreneurial showcase in March, their presentation slideshow listed five individuals. This was a project that connected to Sincere and his friends' sixth grade science class lessons on plant biology and the water cycle, and made those lessons real. It also connected to Sincere's interests in designing eco-friendly structures with new technologies, his funds of knowledge and experience from his mother, and his frustrations at getting in trouble for walking alone to the corner store for better snacks.

As summer approached, Sincere's salsa plants were not doing as well as we would have hoped. Over a few months, we had left them unattended each weekend, in a large building with a centralized HVAC system we did not control. Months before fruit time, the leaves were losing color and the stalks were beginning to droop. I asked Sincere if he wanted to take home his plants so that he could care for them more consistently until they were ready to harvest. We packed up his plants, but when his mom picked him up, she examined them and determined that it would be difficult to save most of the seedlings. She promised she'd help Sincere try to "save what can be saved," and I wished them luck. Sincere replanted them in front of their house as she supervised, and he diligently checked on and watered them throughout that summer, but they didn't make it. That fall, he narrated in great detail each action he took and each response he received from the plants through their process of decline. He did not take his responsibility as a caretaker lightly, and watching the plants finally give up in the summer heat was a frustrating experience for him.

We discussed options to regrow his plant collection again that school year, but by then, Sincere's interests had expanded in scale. He was now asking to explore deforestation and world hunger as systemic problems related to food justice on a more global scale. He formed a new group to explore more portable designs that people could use to address ecological problems across many different communities (this culminated in the design of an "environmental emergency kit" including an informational booklet his group wrote that addressed water quality, protein sources, and organizations to contact in different situations). He wanted to address a diverse range of environmental injustices, focusing on knowledge-sharing to affect change for more people, including people he didn't directly know or see around him.

Pathway resources: the importance of Sincere's sister. Sincere's strategic mobilization of his STEM learning and resources helped him take on leadership roles that expanded opportunities for himself and for others, and especially his little sister. These efforts were enacted within structures of power that influenced how he interacted with the world around him (e.g., persuading support for his pathway through peer social popularity and soliciting trusted adults). His STEM engagement was grounded in ways that Sincere wanted to be and become in his family, in his community, and in his world.

As demonstrated in the bumper pool project vignette, his younger sister was one of the driving forces of his informal STEM engagement over time. Four years older than her, Sincere took on responsibilities to care for her in his afterschool hours, checking in on her frequently even as he maintained a busy engagement repertoire across his community spaces with peers. Amid basketball, STEM work, and social hangouts with peers his age, Sincere helped her with homework, interceded with her daily social dramas, asked for permission for her to visit our makerspace, and even snuck her food from the makerspace's extra snack supply. While Sincere was a popular and trusted social leader among many, his sister was a helpful balancing force who pushed him to remain humble and determined. For example, she had been known to "tell on" her big brother to keep him in line (e.g., when he skipped the program to play basketball as previously mentioned, she often knocked on the door to let me know). He was also teaching his sister at home what he learned in school, to support her pathway efforts even more than he had been supported. When he was learning about circuits and electrical flow, he brought home an LED bulb and a coin cell battery to explore the ideas with her: "She didn't understand how it worked with the [positive and negative] sides so I taught her." I asked what meanings Sincere drew from his relationship with her and how they position each other:

> It means she has someone to look up too and that she's proud of me and that she gets older she wants to be just like me… It makes me feel happy and like I'm doing something right… I know that I'm learning something new so I get to teach her something... I want her to know because some kids in my class don't even know this stuff and I want her to know early because I feel like it will help her.

Sincere explained that STEM learning was his strategy for reaching a successful future for his family as well as himself. "I want the best for my sister. I want her to have a successful life," he added. "I don't want her to go through hard times even though sometimes I might not be able to stop that. I just want the best for her."

Figure 16: Sincere showing his sister his pathway research in the makerspace

Beyond a balancing force for his ambition for power, Sincere also understood his sister one of many of his community's "younger kids" who represented "the next generation," so she inspired him to open up STEM pathways for others as well. He explained, for example, that "I wouldn't just use that [engineering] for myself or for my family. I would actually help other people that are in need of help." He wanted to share access to what he was learning, especially the tools of power afforded to him by STEM-related knowledge and practice. Sincere echoed Tate's (2001) argument that sharing information should be treated as a basic right:

> I feel like it's sharing power to share information… Like educating the people across the city to inform them about what's going on. Like water pollution crises, if they don't know they could continue getting sick from the water, like in Flint. If people know the risks, they might be more cautious. The more people that know, the more people that can help.

This perspective on justice-oriented education through democratization of information was mirrored at school, as well. Sincere's efforts to advocate among classmates the importance and relevance of STEM were deeply connected to who he was and how he wanted to see and position himself. "I've always wanted to make a difference wherever I'm at," he explained. "It's just me. I think that's just me, myself." These efforts were also powered by funds of knowledge and resources he moved across space and over time in order to expand and multiply their benefits for other youth who wanted to learn with STEM. To offer an example of this, Sincere relayed an argument he had with peers about how incorrect battery voltage levels can negatively affect play with powered technologies. He brought different battery types from Afterschool STEM and a flashlight bulb from home to demonstrate. Sincere explained: "I felt good because I was able to share what I learned in Afterschool STEM. It made me feel like Afterschool STEM was helping me out in school. They connect together because I put them together to help me out." He was committed to sharing the benefits he got from drawing learning connections across intersecting community memberships (e.g., he also described traveling with his neighborhood group to the Michigan Science Museum, and discussing there what he had learned in school).

As his STEM engagement vignettes above revealed, Sincere created deep connections to his work that carried across space and time, through his understandings of his roles in that work and the impact his actions could have on others. He argued that healthy relationships were important STEM pathway resources as they could facilitate more successful learning and development. Just as he looked out for his sister, he wanted to use his engineering pathway to look out for others who were vulnerable to abuses of power in the world, including low-income communities like his. "Living good" and enjoying his life was a goal driving his pathway movement, but it was also important to him to help others enjoy their own. He saw his combined goal of personal empowerment and community wellness as a "different" pathway than traditional engineering design pathways:

> I wanna change the world because there are a lot of people that are less fortunate... A lot of people make stuff that's super-expensive, but people can't afford it if they're not doing well. I wanna make things that help people… or do something that will be beneficial to

> the human race. That's the whole reason why I wanna be an architect, because I wanna do different things—and it pays good.

He mused that such beneficial projects could include designing hospitals and additional community centers like his. This, in his words, would separate the future-him from other financially powerful developers who “abuse the right to have power,” including Trump: “He just feels like he is at the top of the food chain. He's president and he's super-rich, so he doesn't care about anyone.” In comparison to such power-abusers, he would be a person of high power using it for the benefit of others besides himself, so “they can have a better life” too.

How Sincere projected his pathway efforts across scales. Sincere desired to support other youth as he advanced along his own pathway. He perceived the power-mediated contexts of his STEM pathway efforts “not as a closed world from which there is no exit,” but as an opportunity for transformation through action (Freire, 2007, p 49). His understandings of his power to change the world for not only himself but for others as well altered our discussions of his pathway’s implications and impacts. Talking about his life movement with STEM as a pathway, for example, inspired him to design a new way to support his peer’s pathways. Unprompted by me, he requested poster-printing help to create a physical pathway support system for his peers in his community. He explained that his peers always noticed political campaign signs along their bus routes to school and from school to the Michigan Community Center. He wanted to encourage and inspire other youth to use more strategy in their interactions across different life spaces, so once we got his poster designs printed he placed them along the same path. His goal was to populate his peer’s physical pathways to and from main learning spaces with signs of lessons he had learned through his own experiences (Figure 17).

Sincere wanted to share his knowledge on how to benefit from social strategizing, as opposed to falling into negative interactions with people of power (e.g., adults) who are capable of helping or hurting youth pathway efforts. His signs reminded and encourage peers in his community:

(1) To develop and maintain helpful relationships with their most important mentors in their lives (parent or guardian), reminding them that a good relationship is mutually beneficial for their pathway efforts.

(2) To treat teachers "how you want to be treated" and give them the benefit of the doubt, as a strategy for gaining more school support.

(3) To befriend people with diverse perspectives, skills, and resources, so peers could mutually benefit from each other's connections and opportunities.

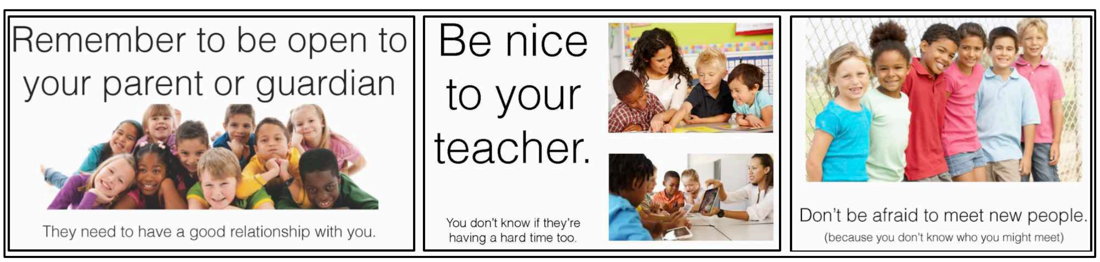


Figure 17: Left to right: Sincere's pathway posters 1, 2, and 3

These signs (pictured above) aligned with Sincere's desire to support other youth in seeking more power like him (e.g., by helping them to strategize movement through power-mediated social structures in ways that had helped him). They also aligned with his desire to use engineering design as a way to follow his ideas towards tangible and long-term changes to reality "instead of guessing what it's going to be like or how you want it to be."

Sincere explained that his informal STEM engagement provided him with a space to do this for himself by letting him "try it out" his ideas in the real world. This, he argued, made his STEM learning feel "more like real engineering" because he had more opportunities to "discuss different things and work together on how we want things to be." He wanted to actually, not just abstractly, build himself and his power to be and become, in present as well as the future:

> Like a month after joining Afterschool STEM, I realized, [with] the things I was doing, I was learning new things about science…and learning what type of person I really was… I'm learning about myself because I'm learning different things that I like. At first, I didn't really know that I liked learning different things… I like learning different things now because if you learn, you're educated and you get to do more… I feel like, knowledge is power. Afterschool STEM Program makes me feel like I know different things and if you know things then you're more powerful. School makes me feel more powerful [too].

He wanted to share such access to developing one's power with other youth. Those signs were one way to work towards that that was easily accessible to him in his afterschool program, so he did not hesitate to take advantage of the opportunity.

Sincere argued that his own STEM pathway was dependent on getting such power-mediated social support from others, which was how he knew what to include in his poster designs. "I want to tell and show people that they need to love each other," he explained, "Even if you don't know what you want to do right now, you can figure it out. You're here for a reason. Don't just waste your life sitting down. Actually try to make a difference." Helping others get active in their own pathways was good strategy, to Sincere, for shared power-building.

Speaking to youth, however, was not sufficient for him. He also wanted to reach out to adults and teach them the importance of helping youth rather than hurting their efforts to seek desired futures with learning and practice:

> Be more truthful. Tell them [youth] you believe in them. Help them figure it out. Help them figure out life. I want adults to believe in me, that I'm hardworking and I don't give up. And I can do it.

Sincere did not want to access the power of STEM learning and practice alone. He wanted that power shared with peers and supported by adults. He was a leader who knew where he wanted to go, and he was working to bring others with him along his way.

How Sincere imagined his pathway's future. As Sincere continued constructing his STEM pathway, he sought to increase his own power to be and become. He wanted to build his future career for himself rather than for the approval of others: "I do it because I want to, not because someone's telling me to. If you're actually doing something you want to, you might do that for a long time." Still, he shared that the approval and advice of more powerful others was an essential requirement for further pathway movement.

With this in mind, Sincere saw a continued commitment to surviving formal educational structures as a necessary strategy to get him to his desired future: "If you're at the best school then you get the best job. My mom teaches me that." This also led to a desire to connect with and learn from adults active in the field of architectural engineering: "I would want to know, are you really the boss? What are the things you have to do? Not just drawing and building but all the math to it and how much time it takes and stuff like that."

In order to continue building his own power with STEM, he would need to continue persuading more powerful STEM representatives that he belonged in their world. With this in mind, he wanted adults in STEM education to take his pathway narrative and portfolio as proof of his worthiness and his abilities:

> I hope that people learn that I am a scientific person... I like learning different things and experiencing something different. It's important for people to know that. I am living good with science… In science, I am a kid who likes to learn different things and who likes to experiment. In engineering, I am a kid who dreams to be an architectural engineer and who likes building things… and I like doing stuff in the community.

Despite an unjust world that sought to diminish or warp his accomplishments as a young Black male learner, Sincere was actively working towards a successful future with STEM. He deserved recognition for this, and he knew that such recognition would help him reach that future more easily.

Beyond concerns for personal development and power-expansion, however, Sincere also intended to continue pushing open access to a diversity of STEM pathway support structures for other youth:

> I care about the community and kids and their education because kids need education to go further in life and be successful. Some kids don't like to go to college and right after high school they just do nothing. Maybe we can change that. Science and engineering is fun and that's the most important thing. But besides that, it can be a good creative job to have, that doesn't make you bored when you're an adult. You always have to have fun in life, and in your job.

Amara and Keke

This narrative explores the interwoven experiences of teenage twin sisters Amara and Keke, two young women creating STEM pathways together. I first met them when they were ten years old, as fifth-graders. They were quick to clarify that they were fraternal twins, different in phenotype and personality. They were very close friends ("and very close frenemies," added

Amara), roommates together in their mom's house in Michigan, classmates at the same public high school, and later, teen mentors together in the Afterschool STEM Program. They led two separately complex but intersecting lives, braided together by environmental inevitability but also by deliberate choice and planning. When Amara first started discussing possibilities for representing pathways to others through this work, for example, Keke shared her concern with Amara that she might waste time on redundancies, as "we have the same pathway" (e.g., they were taking the same school classes, worked the same job, and were both seeking futures with STEM). They shared many of the same interests and annoyances, too (e.g., an interest in YouTube surgery videos and a hatred for hypocritical teacher actions), which helped them to maintain their remarkably close friendship over time. They also described their pathways with STEM learning and practice as "the same for now," as they described fighting the same fight in the same system. Charting a STEM pathway forward together created a navigational partnership. For example, in thinking through possibilities for thriving throughout college, they developed a shared plan, involving remaining roommates for lower-cost off-campus housing and to maintain their tightknit emotional support system. They each named each other as the most important social resource for their individual pathways forward. But they sought a world of resources beyond that support they gave each other, to support their future pathway efforts.

Amara. Amara described herself as a quiet listener, and a voracious, obsessive reader. When I met her, she explained that she was "the quiet one" in their shared friend group: "I've been like that forever." "But when she does talk, she gets loud," her sister Keke added. She "always [paid] attention" in school, and her ways of being and acting in the world often made it feel "natural" for her to perform as and look like a "good student" in classes: "Even when the teacher's just writing on the board, I can figure it out and put it together."

She maintained, however, that school was not natural. It lacked real purpose, besides "getting good grades so I can go to a good college." She desired to know and be shown the purpose behind every practice she was asked to engage in and every task she was asked to complete. She also maintained that school was still a "dangerous" space for her, as she had witnessed racism and favoritism from teachers throughout middle school who had made her cry. And, more than once, she had been subjected to disciplinary action that she knew to be unfair and unwarranted. She wore glasses, which she explained helped her to receive recognition as a "smart person." She also experienced physical problems in her legs when she was younger which made her "sometimes really self-conscious" in elementary school, especially after surgeries when she would arrive at school in a wheelchair. "One of the reasons I got through it was because of Keke. She used to always just cuss me out when I got upset about it," Amara said with a laugh. She explained that her modified walking ability was now simply a small part of her, but it left her with a deeper sense of empathy for what other people might be going through. Amara could often be found reading or writing, and her fast typing and "excellent handwriting" meant that she was typically the scribe for whatever work group she joined: "That always happens." She also always got asked for help in class: "Everybody either wants to copy off my paper or just bother me for help." She loved chemistry, and one of her favorite activities at home with her sister was to "mix chemicals" from their kitchen to "see what happens… And we used to try to make paint from different condiments."

Importantly, Amara's daily ways of being in the world were more than performance for a number, although as she maintained, that was definitely one part of it. She spoke on encouraging "a growth mindset" in youth who want a future in advanced academic study, but she also argued, "I'm a natural at being smart," explaining that her default repertoire of practices fit into traditional notions of student success. For example, "being chill" as a student pushed her grades higher. "I tend to listen more than I talk," she explained. "I'll listen and try to digest the information so I understand it, and then I'll turn it back and relay it in smart person language." Keke offered that her sister's comparatively easy use of "smart person" discourse in class separated them into two different student categories just as much as her listening habits did.

Amara countered, however, that she did not always take her sister's descriptions of her as a compliment, nodding towards more negative social stereotypes of nerdiness she also had to navigate in school. Having a close, trusting friendship with a twin who was louder and more socially outgoing shielded her from some of those negative social aspects of being coded as a nerd in school (e.g., if Amara was overlooked for inclusion in a conversation or social event, Keke would pull her in and reinforce their position as a team unit). "Why would we not be protective of each other," Keke argued. "We're sisters." And after all, Amara argued, "I don't mind being the smartest person in the room. Most of the time it doesn't bother me."

Figure 18: Youth-curated representational photos. Left to right: Amara reading while Keke breaks open speaker parts; Keke in front with a mentor and peers at a program event while Amara is "chilling in the back."

Keke. When Amara's friend René had first pulled her into the program to help with a heated birdhouse design project, Keke was explicitly welcomed to join as well. She came around occasionally that year to see what her sister was working on and to help out, but she declined multiple membership invites from adults in the room. As I got to know Keke as a program visitor, I learned that at home she was an investigative researcher in mechanical engineering. She would tell stories of getting in trouble with her mom for her love of “taking things apart and seeing the inside parts of things” at home (including a story about throwing an old microwave down her basement stairs to break it open).

Keke described herself as “the loudest one” in their shared friend group, and Amara and I agreed. “I was the funniest one too,” she added, to which her sister offered: “That is her natural talent—to make people laugh.” One of Keke’s favorite hobbies was “breaking stuff,” both to observe the mechanical workings of what was inside and to see things explode and get destroyed. “One day I might blow up my house,” she recently joked. “Maybe I’ll really do that when I’m a billionaire, then rebuild my house from scratch.” She was always the first to jump into challenges and take on risks. I once saw her literally jump from her seat at an event when a person onstage asked for a volunteer. I also once witnessed her run after and yell at a man who had catcalled her and her sister as we were walking down a sidewalk in town. In school, she envied that her sister was the go-to peer tutor in their shared classes. But her abilities to “be outgoing and adventurous and act crazy” were a different type of intellectual skill that she argued helped her to achieve her life goals, because it meant that she was more “willing to try new things and go for it,” both in and outside of STEM, with less fear of failure and obstacles. Like her sister, Keke was considering a future in medicine to “help kids and be a superhero as a pediatrician.” She was also considering a future in math:

> I am extremely confident in my mathematical abilities to the point that you could ask me anything about math and I can answer it. My math teachers have [bore] witness to the greatness and it's something I’m immensely proud of.

Keke was on a journey to navigate how to approach educational spaces as her authentic self while still gaining access to the opportunities that came to her sister. Raising her grades over time aided the school-congruent identity work she had desired, but only so far: “Now I think of myself as that nerd sometimes, [but] I still haven’t discovered how to *be* a nerd.” She described a divide between her developing identity-in-practice as a hard-working and intelligent learner and how she still viewed certain peers as operating on a higher plane of visibly recognizable ability. “I want to be super intelligent, like [classmate] who got a 4.2 GPA,” she explained, returning again to attributing that desired achievement to a personal state of *being* that required more upward pathway movement: “School is still hard but I feel like I’m getting up there where the great kids are. The honor-roll-every-year kids.” Her destination “up there” was a position as someone worthy of being recognized as “high-level” and all the different things that could mean across intersecting spaces of capital, privilege, and oppression (e.g., being recognized as someone to “look up to,” “rely on,” and “go to for answers”). Her pathway to that destination of privilege involved defying power structures that sought control over her movement through life (e.g., racial, gender, and class biases that labeled her as not “nerd” material).

While school was not a space where Keke liked doing STEM, her family’s home was a welcoming space of opportunities for exploring and discussing it. For example, she explained that “I talk to myself about science and engineering a lot” in her free time at home, and to her sister Amara as well. “And,” she added, “I talk to Wikipedia. Me and Wikipedia are friends. Like, Wikipedia tells me like, “Oh, you should do this.” And I’m like, OK, Wikipedia.” Beyond her hobby of scientific inquiry with Wikipedia, Keke used YouTube to learn about and envision STEM futures (e.g., watching videos of surgeries). For Amara, too, technology was a STEM lifeline: “I keep medical stuff on my phone all the time and I look up every possible thing I can and try to learn about it." Keke also turned doctor visits into research: "You know how they have like, pamphlets that you get from a doctor's office? When I go to the doctor I take them all."

Keke and Amara's shared pathway. Keke and Amara's shared pathway is one of smartly and strategically co-opting different dimensions of STEM practice towards science with a purpose. They are strategy-sharers and partners in seeking action-oriented uses of their passions in STEM.

As the twins explore a shared pathway, they are seeking individual recognition as well. Amara is seeking a traditionally defined and traditionally recognized STEM pathway, requiring her to conform to and prove legitimacy within traditional power structures of STEM learning and practice (her informal STEM engagement is a helpful resource for her to accomplish this cross-space effort). Compared to Amara, Keke has fewer opportunities available to her to accomplish this kind of traditional structural navigation, so she more urgently and extensively leverages her out-of-school development and engagement with STEM as the center of her pathway, in ways that seek a reimagination of what counts as STEM expertise and legitimacy in the world.

In the fall of their freshman year of high school, the twins traveled to a nearby university to present on their STEM pathways participatory research. Amara used this opportunity to argue her status as a STEM professional. "I am intelligent and love to help people. I inspire, aspire, perspire, conspire, and transpire—the spires of leadership," Amara announced. "My future plan is to be a pulmonary embolism doctor which is called a pulmonologist," Amara told the crowd. Where others had discussed their futures in terms of "dreams," Amara set her feet firmly in the future as a reality to be claimed: "I want to be one of those people that plans out their lives, because I know what I want to do. I have a plan." Keke followed Amara's presentation, getting a few giggles from the crowd as she abruptly shifted gears with an, "OK, guys" and a confident strut across the front of the room. Landing in a bold hand-on-hip stance, she faced the crowd and exclaimed: “Hi everybody, I’m Keke. I am awesome in science and engineering. I learn new things. I am very creative and weird. I’m weirder than most people on the planet… I’m very observant in science and in life…”

Keke wanted the recognition she saw Amara already had, so she worked to define herself and her pathway before others could define it for her. In a follow-up interview, Keke further explained her conception of weirdness as connected to society’s stereotypes of elitist, authoritative nerdiness, and the public recognition of intelligence and ability associated with that positioning (Eglash, 2002). She shared:

> I’ve always secretly wanted to be one of those nerds you see in movies because I thought it was interesting. I wanted to be that smart person that people know is a super genius. People always go to them to ask for the answers… people look up to you and people are always relying on you. I wanted to be that person that people rely on. No one relied on me for anything. They’d go to Amara.

As she evidenced above, Keke’s sister had access to the social and institutional power forms connected to a nerd identity that Keke envied (e.g., recognition from peers in her learning spaces as worthy and intelligent, access to “technocultural” resources, etc.) (Eglash, 2002, p 49). For Keke, positionings of intelligent nerdiness were not easily accessible to her in school. She had witnessed her sister, however, attaining a school identity as an intelligent “nerd” over the years. She attributed this partly to her sister’s near-sightedness, explaining that glasses were a visible marker of the nerd stereotype. “I’ve always wanted to wear glasses,” Keke added. She also attributed it partly to her sister’s comparatively quieter demeanor. Appearing more socially introverted and preferring a book in hand to small talk with classmates were highly visible markers of intelligent nerdiness for these girls and their peers.

Sitting next to Keke, Amara agreed with her assessment of their differing opportunities at school to be recognized as a "nerd." These differing opportunities (e.g., opportunities to gain recognition as a peer tutor in class) led to different ideas about what they could do. "I've been on the honor roll every year. That makes me sound conceited. There's a balance between knowing I'm smart and being conceited," Amara explained, revealing inequitable dimensions of power and privilege built into ideas and public performances/representations of intelligence. Amara's careful avoidance of appearing conceited spoke to ideas of how her perceive nerdiness enhanced her power in school spaces. The honor roll's risk of conceit, for example, revealed that elevation in grade numbers could be a gateway to elevation in social status, one that Keke could not access from her comparative positioning (Eglash, 2002, p 57).

The following narrative documents Keke and Amara's strategic pathway construction efforts, in different and individual ways, but always in a collaborative partnership of support.

Pathway work-in-action: Keke's STEM action for female justice. I start this shared narrative with Keke's entrance into Amara's afterschool STEM community of practice. In this vignette, Keke went from home-contained STEM engagement to multilayered, world-connected engagement with STEM. This, her very first public effort, was transformative development for her and for other girls her age.

When Keke officially joined her twin as an afterschool STEM program member in Fall 2014, her first project demonstrated some specific ways STEM could and should be connected to the world. The theme that year was engineering designs for community safety. Keke and friend René designed and built an anti-rape coat prototype. It looked like any other regular coat on the outside. Hidden in the coat design, however, one of the front coat buttons was secretly equipped to act as on/off button and was connected internally to an integrated high-frequency, high-decibel alarm. Keke and René drew design criteria from their personal experiences of entering heavily social situations like parties, where self-defense information would be more effective if kept secret (e.g., hidden as part of an outfit). Then they dedicated months to learning how to construct electrical circuits, hack/modify alarm electronics, and integrate electronics into high-tech fabric construction. The design was the long-term effort of their 2014-2015 school year, a combination of both social/cultural and mechanical/electrical innovation.

This project started when we asked Keke and her peers to travel around their community to survey people in their afterschool organization and the surrounding neighborhood about the safety issues that concerned them most (Greenberg and Calabrese Barton, 2017, p 14). Then they invested a few weeks in analyzing that information and comparing it with their own experiences and their online research. They discovered that statistically, across the U.S., women of Color under 18 were at the highest risk for experiencing sexual assault. This was their demographic. Keke and René defined these numbers as a call to action for engaging in a high-tech, year-long STEM project with their friends, peers, and community members in mind as their target audience as well as their coalition of support and feedback.

As she learned, Keke invited youth and adults in her community to learn as well. During formal "feedback events" and informal interactions, she became a vocal public educator about violence against young women of Color, risks specific to their community, and engineering technologies her group was using and inventing to combat the problem. Adults also noticed a new habit of her sharing advice with peers who were experiencing what she labeled as destructive relationships (e.g., telling a friend to stop talking to a boy who was pressuring her).

As she continued working to optimize her design throughout the year, she invited peers to enter the STEM program's room in order to see, try on, and provide constructive criticism on the stylish coat prototype (Greenberg and Calabrese Barton, 2017, p 20). Her group's completed prototype made a big local impact that year, beyond the attention received around the coat itself.

In and through this afterschool project, Keke argued that STEM should be intimately woven into and with "real, daily life in the world," including the intersecting oppressions and dangers that real people navigated on a daily basis. She wanted to use STEM an an anti-violence, antiracist, and antisexist activism tool. She took on new roles as STEM-empowered activist for young women, electrical circuits expert, technological inventor, and prototype developer. These roles were publicly recognized and celebrated as peers and community members saw her act for justice with STEM and treated her as a local community leader on issues of women's rights and safety as well as technological innovation (e.g., we witnessed peers discussing the project in other club rooms and approaching Keke for advice on questions of self-protection in romantic relationships). She and René "took back" power, agency, and voice for themselves and their peers, through engagement in a project that was "created with, by, and for community but… also fully theirs" (Greenberg and Calabrese Barton, 2017, p 21).

Keke and René addressed complex needs across STEM, sexuality, community, and society, drawing from experiences and expertise across space and time. By questioning and acting on the multilayered contexts within which they were learning and growing, they created space to develop themselves on their own terms. As Keke explained, "You don't have to change yourself to be a different person … [You] don't have to do things that you don't want to do that other people are telling you to do" (Greenberg and Calabrese Barton, 2017, p 22). They also reorganized STEM processes to open up boundaries of practice and interaction that define STEM engagement. For example, they publicly debated incremental findings throughout the investigative process to fold complexity back into the data, upending traditional scientist-participant hierarchical boundaries by gathering community advice. They also redefined leadership with STEM as communal sharing of opportunities to engage in action (e.g., inviting friends into investigative data-sifting/interpretive conversations that drove the direction of their engineering design process).

Individually, Keke also created out-of-school spaces to push for new definitions of herself, in and with STEM and this project. For example, she gained recognition as a tech leader who could understand some specific experiences of Black, female community members and could use that understanding to enhance her technological design. She got "nerdy" with engineering technology design in ways that were directly connected to social issues she was already navigating (e.g., determining electrical flow as a part of troubleshooting circuit construction to complete a jacket her friends would want to wear). Her acts of nerdiness, then, went deeper than performance. They were real practices, directly connected to her interactions with her experiences of the world around her.

Figure 19: Keke and partner René constructing and presenting their coat alarm design

As I continued teaching in the program, I witnessed that project maintain its position as an active artifact of female power to act with STEM in our program, even three years later (e.g., as a teen mentor, Keke used the coat to teach younger female club members about fighting back in a male and violent world). As Keke explained, “I want to help those girls, to help them to not do things they don’t want to do, and to not … have their bodies exploited if they don’t want to” (Greenberg and Calabrese Barton, 2017, p 18). She had mobilized STEM learning far beyond the severely limited scope of how school defined it:

> Because for school you just have to do it for grades. And I don’t have time for that. I need to connect the learning the way I want. I want to connect it to stuff that actually matters in my life… to things I actually care about.

As demonstrated by this quote, Keke’s STEM connection-making was an act of urgency, because she understood the world and its actions and problems as interconnected.

Pathway work-in-action: Amara wanted purposeful STEM. For both girls, connecting learning and practice to the real world gave their STEM engagement purpose. For example, Amara explained that STEM learning could help her “get life skills in the job of being a doctor,” and this gave her a purpose to survive “boring” school science. Amara found additional types of purposeful connection-making with STEM through her out-of-school work.

For example, in discussing her public transportation heating system engineering design, a project she completed with Keke in their seventh-grade year in our Afterschool STEM Program, Amara explained: “With that project, there was a purpose for it. People need it to get where they’re trying to go. You shouldn’t just make something because you like to make it. It should have some type of purpose.” The abstraction of school science, “pure research,” and the self-interest of a lot of corporate engineering design were insulting wastes of time for someone who saw tangible community needs for innovation every day. In her afterschool program, STEM held more meaning. Her work felt important to her, because the problem space she was exploring felt important to her community.

Amara grounded her science and engineering engagement in her experiences of life in her city, for herself and for important people in her life. Her responsibility in the project, a heated bus seat design, was built from her years of experience as the daughter of a city bus driver. This life experience provided Amara with productive imagination from real frustration. For example, she knew from personal experience that the seats on those buses were uncomfortable: “If you stay on there for long enough because your stop is far, than *no*,” she stated emphatically, refusing the injustice of a sore behind on a cold, hard seat that she had felt and witnessed countless times. While unpleasant in itself, Amara understood that this seat design issue could become one indignity too far for someone already having a particularly rough experience: “Sometimes you have to hop off and hop on another bus and there’s no seats, or it’s hot, or you have to stand, or it’s cold.”

Amara knew their mom’s field of work acted as a window into their city’s social and economic injustices, through experiences they had witnessed and stories their mom had come home and told them. “I get on the bus enough to know. I see it every time I get on there,” Amara explained to me in an interview. “Plus I hear my mom talk about a whole bunch of stuff that be happening on there... People are very dependent on it. The stories I’ve heard.” As they discussed their knowledge on this issue, a depth of empathy for other community member’s personal and systemic struggles surfaced clearly. This project was not just learning for learning’s sake. This was real life. Bus design held enormous implications for people in town, “especially if they don’t have a car,” Keke added. In their commitment to this work, the sisters tied themselves to their community. This was STEM with a purpose.

Pathway work-in-action: a purposeful application of STEM. This vignette details the type of purposeful and connected STEM engagement Amara was describing in the previous section. Here, Keke and Amara improve a large structure mediating life in their community, through purposeful application of STEM learning and practice.

Keke and Amara joined forces in their heated transportation system design project to take purposeful action with and through STEM. While they both described this project as purposeful, they differed in their descriptions of what those purposes were. For Amara, purposeful work was grounded in local knowledge, grown in shared community space, and consequential in concrete action. It was about co-opting traditional STEM learning and practice for results "that actually matter" "in the real world." For Keke, the project also helped her to understand her own capabilities as a STEM expert who truly belonged in the real world of STEM practice.

As they delved into their shared project, the sisters' desires to address multiple aspects of transportation frustration in their city led to their decision to each focus on a different component of a system-wide solution. This two-part project was also a two-person coalition for commuter justice in the city. Together, they redesigned multiple components of their city's public transportation system to address multiple dimensions of winter rider comfort simultaneously. Their different perspectives on the work and the meanings behind it led to different types of engagement in the project, as well as different consequences for their own development along STEM pathways that mattered to them.

Amara concentrated on the on-bus riding and sitting experience, and Keke focused on the waiting-in-the-cold experience. Amara's solar-powered, heated seat cushion design was meant to provide some soothing comfort to "tired and sore" riders' "old, tired legs" at the end of a long work day. She learned how to use a sewing machine with the help of a program mentor in the makerspace, and she applied this new skill to sew a heater circuit through a fabric-covered cushion that connected to a hand dial for individual rider temperature adjustment. Keke designed a pedal generator-powered, radiant halogen and conductive heating system for a bus stop shelters. To avoid forcing riders to pedal for warmth, the design incorporated a rechargeable power storage system. Keke used an old shoebox to represent a bus shelter, outfitted with a 12V heat lamp, a 5V heating element on a cardboard miniature bench, and a hand crank representing a bike-sized pedal generator. Both sisters became entrenched in reworking their two-part design to be more accessible to older, disabled, and "tired" people in their community.

Figure 20: Left to right, Amara and Keke with their prototypes

As Keke completed this construction work, she volunteered to write descriptions for both of their prototypes; Amara accepted the offer. Keke also took over the design of presentation slides to present her and her sister's work to the public. Her descriptions included relevant physical science concepts she had personally learned along the way:

> It heats with high-Wattage halogen lamps (radiant light energy) that will be located below the bus shelter's bench, because heat rises. Also, my system includes surface heating elements (like a heating pad) on the bus shelter's bench (conductive heat energy). Heat comes from three directions: bottom, side and side. The radiant energy from the heat lamp comes from underneath the bench, the heating element on the bench's surface heats

> your body directly, and the heat also comes out from the side walls of the bus shelter, through heated wires. That's important so that your whole body can be warm, and you won't be cold.

This quote went beyond simply representing process and product for her and her sister. Keke was sharing their work, but this was not just about their project. It was also an opportunity that Keke took advantage of, to advertise her presence on the team as a recognition-worthy STEM expert.

Pathway work-in-action: Keke's pathway realization. As mentioned above, their shared project was more than a sisterly effort to help the community. It was also a space for Keke to further develop her individual STEM identity-in-practice, and she took advantage of it as a pathway-constructing strategy. As the following vignette demonstrates, even though this identity-building effort was purposeful, Keke surprised herself with her level of achieving this goal.

One day during the project, Keke and I were clicking through YouTube searching for how-to videos to help Keke figure out how to construct a circuit in a way that would allow the hand-crank generator to power up the heat sources while simultaneously recharging the batteries. Keke landed on a video of a man who was making an auto relay. She began drawing on paper a circuit diagram that was being shown in the video. She had alerted me to her suspicion that the man had written something down on his circuit diagram incorrectly (he had written the term "open contact" and she knew her circuit needed to be "closed" in order for the heat to turn on). I agreed with her that she was wise to create her own, different version of a circuit diagram that would accommodate her power source, switch, and resistor design needs. She moved lines around on her paper, adding written descriptions to clarify parts of the diagram that she was changing to create the kind of schematic she had in mind for her project.

At the end of the afternoon, Keke instructed me to photograph her diagram drawing so she would have a copy handy to guide her circuit work in the following week. She requested to take home the original paper version in order to frame it and hang it on her bedroom wall. When I asked why she wanted to display it, she paused, quietly looked at the completed diagram in her hands, and answered with a small, matter-of-fact smile: “I'm a science person now. I’m surprised.” And with that, she carefully folded up her diagram, slid it into her purse pocket, and gathered up her backpack and jacket to leave.

Amara paused as Keke exited the room. She turned to me and, with eyes wide, exclaimed that she had never heard such a statement from her sister before. Looking back to layer some contextual analysis onto this discovery, Keke explained a few months later: “I thought science was so nerdy that only weird people would be into science. I always thought, ‘Oh, you’d do science here and there,’ but never actually become a scientist.” Here again, she had named science as “weird” and “nerdy,” but in this case she more explicitly shared her secret doubts that she would ever actually embody that role in a way that felt deeper than a performance. She had claimed a STEM pathway toward medical school and a career as a pediatrician, but she had maintained a contradictory underlying idea that science would be something she would only really do “here and there.” But here in this moment she had experienced science become a part of who she was authentically. This was why she named this identity work episode as “one of my top life moments with STEM.” In her stating “I’m a science person now,” she claimed a successful crossing of a lingering disconnection she had felt for a long time. This was a big moment of STEM pathway movement, and a consciously experienced shift in position. The shift she had felt was as much a surprise to her as it was to her twin.

In this project, Keke advanced along her STEM pathway out of school in ways that she was not able to access in school. Suddenly, with an artifact of the process in hand, she realized with surprise that this advancement had helped her to transport herself into a new identity-in-practice (Tan, Calabrese Barton, Kang, & O'Neill, 2013). It was a new position along her STEM pathway, with a new perspective on her efforts and capabilities, and with a new relationship of authentic, embodied connection with science.

This moment was built from hours and miles of bus rides the then-12-year-old twins had taken together, and Keke's developing funds of knowledge as the daughter of a city bus driver. It also involved many months of sustained STEM engagement for real-world purposes after school. Keke had researched public health and safety related to public transportation, calculated potential time spent outside based on different bus schedules across town, inquired about and/or calculated voltage and amperage requirements of different outdoor heating systems, read about human-powered generators and shopped for the parts to build her own, learned about battery power storage and circuit constructing… not to mention the time she actually spent designing, constructing, testing, refining, and presenting her prototype of a working, eco-friendly heater system for bus stops. Suddenly, after all that time, Keke noticed that she was not standing where she used to be. She had moved through a transformative process of becoming while mobilizing, role-claiming, acting, and learning. Looking back, she realized that she had leapt forward along her pathway with STEM.

Figure 21: Keke and Amara's mom photographing Keke after their public presentation

Keke and Amara wanted to take up STEM engagement as a way to engage differently with their shared world. Here, Keke was also claiming a change in her engagement with her lived identities-in-practice in that shared world. She felt she had finally accessed a "science person" space of being and becoming that she had desired for a long time. What she accessed provided a new status or position in the world, and a new space of practice, that connected to traditional definitions (and stereotypes) of doing "science" and being "scientist."

Pathway resources: spaces and opportunities within them. Keke and Amara's pathway construction work took place with power-mediated sociocultural interaction with STEM spaces and the relationships and resources that made opportunities accessible within and across them. The girls explained that the ways in which different STEM spaces were constructed affected their access to opportunities within them. For Keke, Amara, and those around them in their community, science was undesirable within middle and high school spaces, yet desirable in some other spaces of daily life practice (e.g., at home, Amara loved making slime and other concoctions, and Keke loved taking apart electronics). It was also desirable as a career across future spaces of learning and practice (e.g., a medical career was described as connected to social and economic capital, and to exciting practices that could change the world). Science in school spaces was undesirable because it had become defined as closed, judgmental, abstracted, unhelpful, and “just plain boring.” As Amara explained, “Science class is the one nobody really likes or wants to go to.” In their afterschool STEM/maker program, however, And as her favorite show Grey’s Anatomy demonstrated, medical science career spaces could stimulate, entertain, and fulfill one professionally. They could also help people who Keke explained “need,” “rely on,” and “look up to” medical professionals.

Keke shared Amara’s concerns about where she was allowed or welcomed to be and become more active in STEM. In discussing her engagement in our afterschool program, Keke stated: “I am active because I do stuff. I eat, I work, I type, I write, I look, I feel, I see, I make things, I help people. I made a lot of stuff. I have a website. I also have inventions too.” She depicted her STEM engagement in school as an opposite experience. In seventh grade, for example, she explained: “I hate not *doing* science in school. All we do is sit there and do notes. Do nothing. And then when the quiz comes up, you don’t know how to do it.” Looking back on some positive changes that happened for her in eighth grade, she explained: “We had a real science teacher and so we actually did science sometimes. Sometimes we still didn’t because our class was bad.”

Spaces of STEM in school provided some extremely negative experiences for both Amara and Keke. Throughout her sixth and seventh grade years, for example, Keke maintained a D average in science, and Amara often complained that her science teachers did not care. “All our science teacher used to do was make us take notes and I felt like I was never learning anything,” Amara explained. Keke rose to A’s and B’s in eighth grade, and Amara rose from “A’s, B’s, and C’s” to “straight A’s”. Amara described their teacher that year as “just a super freak. She couldn’t trust us to do nothing. She was always so concerned. We’d sit with papers because she couldn’t trust us with projects.” Amara credited this perceived teacher paranoia and rigid, authoritative control for the fact that eighth grade science was boring as well, lacking in any project-based or hands-on learning, or any applications of curricular concepts to real life. In addition to these experiences in science class, Amara and Keke had experienced a traumatic course of events in their engineering courses at their STEM academy. During their seventh-grade year, their engineering teacher had allegedly been fired for violent misconduct against a student, and he was never replaced. Eventually, the school dropped its STEM certification altogether.

As eighth graders, when Amara and Keke started mapping out their STEM pathways in a pilot for this project, they argued for teachers and administrators to be represented as "stop signs" slowing down pathway movement, or as active builders of dangerous blockades they were forced to dodge or confront. During one of these meetings, Amara shared a story about how earlier that same day, her science teacher had called in the school's police officer to remove her from the classroom because she had confronted a student who had just stolen her phone. "My mom would have killed me if I would have come home without my phone," she explained, revealing a disciplinary trap that left no room for escape. Keke backed up her story and added further context, explaining that the teacher showed favoritism along lines of race: "He'd be talking to the white kids like they're best friends… I'm too black for him."

School was not safe, and teachers were not allies; overt racism made this especially true for students of Color in Keke and Amara's middle school. According to them, getting "pulled out" or "kicked out" of class and sent to the principal's office, or put into the hands of the school's police officer, was something only students of Color had to worry about. When the adults at their school were not active pathway impeders, they were described as oblivious and/or apathetic side characters. As Amara explained, "They don't know because they don't take time to know." For example, when Amara was forcibly removed from her science learning space that day, she was sent to a principal who "handed out direct suspensions like candy," someone who wasn't known to take an interest in context or cause.

Keke and Amara explained that exploring these types of issues of injustice within specific spaces (e.g., the ways school authorities performed) affected their definitions of those spaces and their strategies for navigating them. Within a desert of middle school apathy, for example, Amara had felt racist injustice viscerally when she had seen white students get the emotional support she was continually denied. As a result, she had learned to put up emotional walls. "We say we don't care because we don't want to cry in front of them. After I walk away, I start crying," she shared. These strategy-building experiences critically influenced Amara and Keke's efforts to move across and enter other, alternative spaces of power in STEM.

Keke and Amara both wanted to gain respect, recognition, and support in official science spaces. They wanted to leverage those resources to power and support their movements towards future science spaces they wanted to access and leverage (e.g., medical schools and hospital rooms). Where school did not always open its doors to support these efforts, the Afterschool STEM Program provided another option for accomplishing this work. For example, Amara stated: "In [the afterschool STEM program] I have accomplished a lot more than what I do in science class… I've gotten to learn and make things that I never knew about before." While school science and engineering felt like a never-ending list of rules to memorize, regurgitate, and follow, Amara felt like rules made more sense when she could enact them in practice:

> The same rules that apply in regular science happen in [the afterschool STEM program], like protective gear is needed, etc. But when you're doing it in [the afterschool STEM program] it just doesn't seem as stupid. At school they give you papers and you have to do worksheets on what protective gear is. It just doesn't make sense to do a worksheet on

protective gear. But in [the afterschool STEM program] you talk about it and then you actually put the gear on and use it to do something.

Keke and Amara wanted people outside of their city to recognize and acknowledge the work they had completed inside their community with STEM, in order to support their efforts to advance with STEM across spaces of greater power and access. Seeking recognition for her geographical movement already achieved, Amara described doing and thinking science across a wide swath of different locations across her life, including moments from her kitchen, her backyard, the park, and her after school program at her Michigan Community Center community center. Keke added that while she did not "*do* science in a lot of places," she found power in the idea that "science is everywhere." She continually wondered about the natural and manmade world with a scientific lens as she traveled across daily locations of her life. For example, she recently shared her fascination with the architecture of her city, what laws of physics made it possible, and what she could further learn on those topics: "Not everybody knows how a building is made, [or] why you have to have so many layers on a building." She described her ideas as connecting fibers that bridged and mobilized her efforts to learn and practice in STEM across space, including spaces of science learning and practice online (especially "when I'm seriously bored").

To make more equitable and sustainable change for their lives and the lives of others, Keke and Amara also wanted to do more than simply access opportunities within spaces and positions already defined and bounded. They wanted to restructure the scientist identity-in-practice as someone connected to the community in which they lived, someone engaged in making the world better, and someone aware of local knowledge funds' importance and legitimacy in professional STEM practice. They wanted to restructure STEM as a space of learning and practice that "actually matters." They wanted membership to the world of professional science, but they also wanted to make fundamental changes to that world. They needed to play the game of traditionally defined science in school to move towards the social futures they'd imagined for themselves. But out of school, they operated on a different STEM playground, with a much different vision of what STEM was, who STEM was for, what STEM could do in/for the world and the people in it.

Through working on science and engineering learning and practice out of school, Keke and Amara found resources across their community that helped them to restructure how they interacted with and took up ownership within STEM (e.g., connections to STEM professionals and mentors through their afterschool program). These resources also helped them to redefine themselves with and within STEM. This supported their movement across different STEM spaces as well as their development of more complex perspectives on STEM and their relationships with it. For example, by eighth grade, Keke began to approach new science classes as someone with who was "already an expert" because of her experienced positionings out of school. They could leverage the power games of school-defined science achievement while still realizing more radical possibilities of out-of-school STEM engagement and building an out-of-school portfolio of work. This was key to Keke and Amara's efforts to restructure learning pathways for themselves.

As Keke and Amara discussed institutional support for their own STEM pathways moving into high school, aging out of our middle-school-targeted STEM Program was a big concern. They described losing membership as losing an important STEM pathway resource they had counted on to support their forward movement. They kept in contact with me during their first fall semester of high school as a continuing bridge to the program. After about a month of this, they began volunteering at the Afterschool STEM Program once a week as teen mentors, seeking a closer continued connection to the program. Within another month, they had persuaded our program director to turn this into a paid high school job that they shared. “I just want to keep doing it through high school,” Amara stated.

As the years progressed, Amara and Keke became well-known by younger members as cool, older role-models in STEM. Keke took on a more intimidating role as a teen with important ideas and skills and little patience for immaturity in the youth she would help out in our afterschool STEM program—the no-nonsense helper. We began asking her to assist the rowdier, louder youth in the room, and they looked to her with respect for multiple reasons. First, they recognized her as a more seasoned near-peer mentor who had recently handled many of the dramatic middle school social hurdles they found themselves in the midst of grappling. Second, they respected her ability to push back on their attempts to monopolize interactions in the room, as a mentor knowledgeable in popular-group practices and ways of being (e.g., she demonstrated skills in answering teasing bids for attention with a teasing response that shut down attempts to position others with lesser power while pivoting group dynamics back to a focus on STEM content-in-practice). Amara became known as the go-to person for writing structure and idea-framing help, and as the more patient and reserved mentor of the two. She was the easy-going science writer who could guide step-by-step thinking, questioning, and argument communication. Amara described herself as a “logical, reasonable, and inquisitive” teen helper. She also added that being a unique human being—“being different, not being like everybody else”—helped her to stand out as a mentor, because it helped her to understand how “everyone’s different” in their own way, too: “I think that gives me I different perspective of the world.”

During an interview in eighth grade, Keke and Amara stated that they were committed to continue their engagement with out-of-school STEM through high school, and to become mentors for other youth in STEM. Keke elaborated that she wanted to help other youth build connections to STEM and the world around them in the same way she was able to in the program:

> I feel like a nice person in [the afterschool STEM program] because I help people with the inventions I make. I wanted to help people learn more about science and what science does. Not a lot of people like science. They think it's dumb. I think science is cool. People can try it out and see that it's cool, just like I know it is.

She explained that mentors were essential connectors between a space's resources and youth seeking support along their pathway movement. Good mentors "actually try to understand what you're trying to do" and then leverage institutional resources to help make it happen. Keke wanted others to "look up to" her as "a role model to somebody. Teaching them like what to do and how to do it."

How Amara and Keke projected their pathway efforts across scales. As Amara and Keke worked on this project with me, we spent a lot of time debating together the best way to represent their pathways to others, beyond this written narrative. It was important to them to effectively grab the attention of adults who held power over their pathways and those of their peers. They argued that many people holding power over youth pathways (e.g., middle and high school teachers and principals, college admission deans, employers and internship hiring managers, researchers and program designers, etc.) may need to be persuaded to help change support structures. They talked about this writing portion of the project as something they were willing to support "to help Day graduate," but not as an endpoint to their work.

Keke wanted to reintroduce two things to the world: STEM, and herself. She explained that if they could see what she sees, maybe the world would better understand how cool, not weird, STEM engagement was. Maybe they would not dismiss it as only for snobby, elite nerds: "I want to show that you don't always have to just be the one that's in college to know what in the world science is. There's kids like me out there doing science right now." She also wanted this work to explain, "I'm pretty damn smart. A lot of people, they don't really do anything. And people don't really like science. I'm that one weird person you know that's in science. I'm very adventurous." For Keke, publicly embracing her "weird" curiosities (e.g., phenomena peers found gross or strange, like dissected organs) was a social risk, as was publicly claiming and doing STEM (e.g., McGee & Bentley, 2017). As such, Keke defined her risk-taking abilities as part of what made her uniquely positioned towards future success in STEM. Her ability to accept risks in order to claim her path was evidence of her strength as a pioneer: "It says that I can actually lead somebody. I would be one of those leaders that knows how to lead." Making all this public could help her get recognized by more powerful others (e.g., college admissions people) as somone who "knows what she's doing." After all, Keke explained with confidence, "Everything I've done so far, people don't usually start this until their twenties." Keke's movements towards her future were also speaking back to systems of power that sought to disrupt her movement and reverse it or divert it away from the center. As she pushed ahead, she saw her progress and the difference it could make.

Amara also wanted a public impact, especially with "people that are going to give me a job." This would involve pushing back against dominant, oppressive narratives about who does what in STEM. For example, when I asked her what she might want such people to know about her, she stated with a fist proudly held straight up in the air:

> I'm a black person trying to solve our nation's problems. I'm making a difference. You usually see people like Einstein, white, old people, making a difference. That's all you usually see is like white, old people making a difference. Like, the people that discovered the telephone, the people that discovered electricity, the kite key thing, they were all white old men… I'm a community person trying to solve community problems.

She was aware of the systematic oppression that young Black women face in life and some of the ways it played out as underrepresentation in STEM (National Science Foundation, 2019). She recognized and shouted back at her historical positioning, understanding her power to work towards change with STEM as she continued to develop that power further (McGee & Bentley, 2017; Zeldin & Pajares, 2000). She wanted to put the world on notice. "People always underestimate people because they just assume," she explained—and she refuses to be put in someone else's category of bias. So, "I want it public that I have a plan for my pathway to doctorhood... I want them to know."

As a next step, we discussed ways to turn what we learned and organized in the writing process into more active and living tools for structural change (e.g., professional development products). We discussed images, slideshows, video, audio, tactile objects, and drama-informed products. They knew they wanted to use visual tools, to map out their lives in some artistic way. As I showed them pathway maps that adults had drawn during a pathways workshop, Amara explained that "using a regular map is boring" and would not achieve their goals of persuasion and change. It would not make adults "feel" the way they felt when engaging happily within science and engineering spaces, or when being systematically turned away from (or being marginalized or silenced within) such spaces.

Amara wanted to make adults aware that her pathway matters and deserves more support systemically, but she did not want to personally teach that lesson. Instead, she liked the idea of an action-oriented tool that could perform this task for her. She explained that she wanted others to learn about her pathway, but to "have fun doing [that learning] somewhere else, not in my space." For Amara, it was important that people experience her pathway through her eyes and learn from it. At the same time, she did not appreciate the burden of educating her oppressors about how they oppress, the burden that too often gets unfairly put upon those who are racialized, marginalized, and oppressed. She did not want to continually explain her pain to those who were continually causing it. She wanted a technology that could help adults to "just look at it and figure it out" for themselves—a pathway revealing presentation she would never have to attend.

We made plans to discuss design criteria for an awareness-building tool that would force adults to acknowledge youth pathways, without forcing youth to be present. Something to help adults experience pathways of life and learning the way that youth experience them, with all the danger, stress, tension, hope, desire, disappointment, and triumph. During our first meeting together on this topic, Amara shared an epiphany: "We should create a GTA5-type experience," she explained, to "build out a virtual 3D map game of where I do the science, technology, and math stuff." Keke loved the idea. Building on the Grand Theft Auto video game template (in which a player takes on a character's identity), they would design a virtual reality role-play experience in which educational leaders could take on the identity of a STEM subject learner/doer and experience a day in their life. Just like in Grand Theft Auto, there would be challenges to complete that involved danger and violence: "We can make people go to class, have teachers call you a b*tch and then leave a message on your mom's phone telling on you for walking out of class when she yelled at you," Amara explained excitedly, in a callback to one of her worst days at school that she had described to me before. Their plan was set: the girls would "make" adults experience for themselves the broken world of learning they had created and maintained.

Giving adults a taste of their own medicine was a plan that gave their pathway representation work new purpose, direction, and urgent meaning. Keke got started by drawing out a storyboard of her life as different "levels" of achievement. Amara set out creating a 3D model of her school with playing cards and duct tape. She enlisted my help to form a collection of game characters out of thimbles, markers, and tape. She directed a dramatic expository scene with stop motion animation software on an iPad, depicting a girl who gets bullied in the cafeteria, confronts the bully in science class, and is sent to the principal's office for her actions.

With an initial outline of play in student-mode completed, the girls discussed potentially also building a game-play option in teacher-mode, to share awareness with students about how teachers can feel. "It can show both perspectives for why both sides can have problems and have different ways to solve them," Amara explained. "People always assume it's the way the student was raise and the way the teacher can teach but sometimes, it's a little bit more. Sometimes they just have different ways of dealing with things."

How Keke and Amara imagined their pathway's future. As a teen helper at her after school program, Keke achieved a next-level mentor status in STEM while continuing her own practices in "coming up with ideas that no one has ever thought of. Like I'm a creator. An inventor." She was working with one group to develop an emergency water testing kit as a localized response to environmental injustices in Flint and across Michigan. She was also mentoring a group of girls working to support documentation and reporting of violence against women with hidden camera technologies. She and Amara were also participating in ongoing mentor training workshops with university partners and in research conference presentations on their work as STEM mentors (e.g., at the 2018 American Educational Research Association annual meeting in New York). Keke could feel the momentum of her pathway to the future as she moves into new spaces of professional practice and power. She described it as opposite from experiences of powerlessness, boredom, and disconnection in school and other spaces, "When I'm just like sitting there, agreeing to everything, not really caring about what I'm doing." Her Afterschool STEM Program work, for example, made her feel as if "I could be the next—who was the person who created peanut butter? [Washington Carver?] Yeah, I could be like him." She also described her relationship with me as a STEM mentor as affirming to her that she was becoming a STEM person more fully as well:

> …You're like, sort of like me. You're like very outgoing and very fun, and you're not just chill at all. You push us. And so, you taught me more about science and engineering. Helping with other kids in the room, it made me be more like you. We are like two people of the same thing. And so, technically since you're a scientist, it makes me feel more like a scientist or engineering person.

Finally, she acknowledged that some of this momentum she felt about her pathway to her future was intertwined with the easy fact of getting older: "I actually am more mature than I was before," she explained. "I used to be like really, really, really childish. But now I'm only two really's."

Amara was also putting into practice the plans that she had been making for her future. This included getting a job in STEM (as a teen mentor for our middle school-geared science and engineering program). It also included exploring college programs for pre-medicine study (which she began this past summer with her mom and sister across the state). “I want to be one of those people that plans out their lives because I know what I want to do. I have a plan,” she argued. “I feel like a lot of people don’t have one, so they just go along with stuff until they figure out one. But I think it’s a good thing to have a plan.”

Thematic discussion

The five narratives presented above use narrative co-construction with rich detail to describe five different youth STEM pathways still under development today. These five young people worked to construct pathways with STEM learning and practice in multiple different multi-layered ways. As we began to look over the above-detailed narratives and their pathway portfolios (Appendix A), themes began to emerge in their experiences. These emergent themes included the following:

- Resources
- Time
- Space
- Power
- Purpose
- Re-seeing
- Action
- Becoming

These themes were interwoven across youth experiences of STEM pathway construction. Youth constructed STEM pathways across *space* and *time*, creatively restructuring pathway components in order to mobilize STEM *resources* towards their desired learning and development futures. Where traditional STEM *resources* did not exist or were inaccessible, they remixed nontraditional ones. They took *action* to redefine and restructure the world around them towards productive STEM pathway uses. All of these efforts were dynamically interwoven with inequitable *power* systems of education and of life, and youth critically explored their ideas about the *purposes* of engaging with structures that were imperfect and inequitable. Their multidimensional efforts were shared tools for *re-seeing* what could be possible in their lives with STEM as well as how they could engage in this research with me to affect change for other youth.

All of these efforts across space and time affected their possibilities to conduct their desired efforts of *becoming* along their STEM pathways. For example, Amara stated, “In [afterschool STEM program], I am a science and engineering double major,” but she did not often feel that way in school. Such efforts shifted and informed youth STEM pathway actions, leading to new opportunities to be and become with STEM across life. In the following chapter, these themes are explored in depth.

Chapter 5: Analytical Findings as Cross-Cutting STEM Pathway Themes

In this chapter, I share findings that emerged from this study as themes. Three themes cut across our co-developed findings related to youth STEM pathway construction efforts, including a) navigating the world as it is, b) working towards the world as it could be, and c) processes of becoming. These three cross-cutting themes show how the youth in this study experienced and made sense of their pathway construction efforts within and against the worlds in which they live. The dimensions fit together to form my analytical model of youth pathway construction.

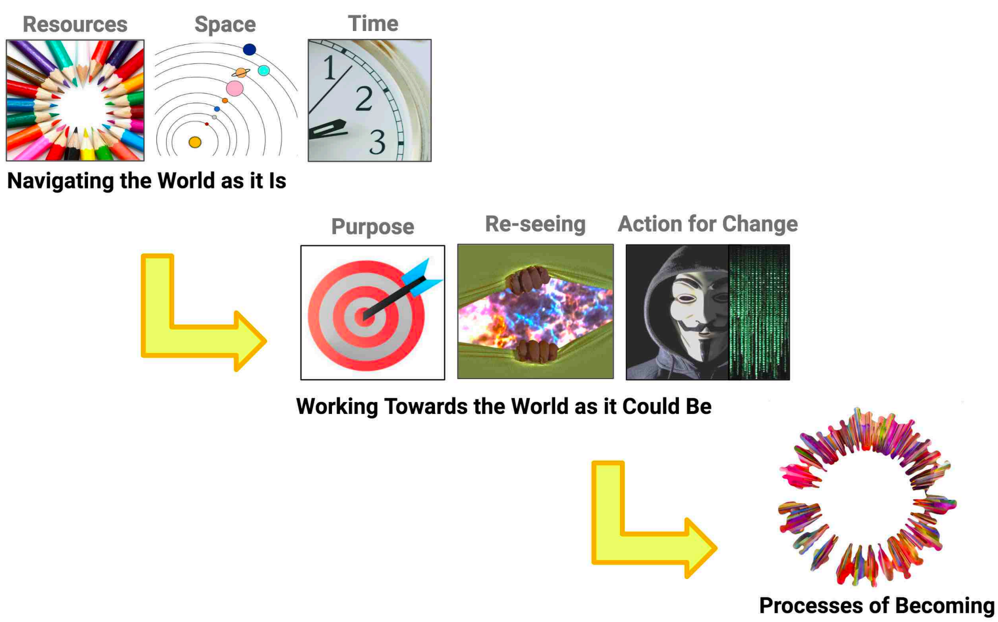


Figure 22: Youth pathway construction model

The first cross-cutting theme, *the world as it is*, describes the world that the youth in this study are navigating as they learn and grow, and the opportunities and challenges they face. Youth are living in the world around them now. Even as they are looking forward and seeking a different future through constructing pathways to that imagined future, they are tasked with tending to the terrains upon and across which their pathways are developing. What these terrains look and feel like influences their experiences of pathway-building and affects the outcomes of their efforts. Youth and others along their pathways act upon and shift various pathway terrains over time, so while this theme focuses on what is, it also reveals what is always in motion or shift (and how youth navigations can sometimes influence shifts). This section will focus on three orienting dimensions of living while working towards a future in STEM: *resources*, *space*, and *time*.

The second cross-cutting theme that I will discuss in this chapter is *working towards the world as it could be*. Youth pathway processes, such as the construction of new futures and the changing of worlds around oneself, requires force. This is where this second cross-cutting theme of *working towards the world as it could be* comes in. I examine three cross-cutting dimensions that speak to this force youth leverage in shaping a world that could be through their pathway work: *purpose, action for change,* and *re-seeing.*

Finally, the third cross-cutting theme taken up by youth in their pathway authoring relates to processes of *becoming* for themselves and for their peers and communities. By becoming I refer to further opportunities for learning and practice moving forward, not to an endpoint or stoppage. Dimensions of becoming are processes of dynamic interaction with the world and with others as youth move towards their desired futures with greater momentum and strength. This is a process that is ongoing and in tension with power structures that continue to seek control over youth efforts. I will examine how youth engaged in a process of becoming as their pathway construction efforts moved them forward towards their desired futures with STEM.

Lastly, I will discuss *power* throughout all sections of findings below, as a sort of fourth cross-cutting theme, in order to acknowledge and address how power is always implicitly present and working across all themes and contexts of youth pathway construction. For example, power is a pathway-framing force, externally structured and maintained across space and time by adults and the sociocultural and historical structures they uphold (Bourdieu & Passeron, 1990; Leander, Phillips, & Taylor, 2010). It is policed across learning spaces by historical contexts of whiteness, masculinity, violence, fear, and domination (Freire, 2007). It takes on a multiplicity of forms and actions across life terrains, such as in the traditional structures of school lessons that rely on banking practices and assume student ignorance (Freire, 2007, pp. 72-73), in out-of-school community structures that demand constant adult supervision and direction over youth practices (Leander, Phillips, & Taylor, 2010, pp. 352-353), and in how power dynamics of STEM educational community membership get internalized by youth over time and affect their self-concepts of capability and belonging (Calabrese Barton & Tan, 2018a, p 28).

Each of the three cross-cutting theme sections includes an overview defining the theme and cross-cutting dimensions of the theme. See Table 9 for dimensions within each theme and sub-categories within each dimension, including different recorded forms of dimensions and important youth practices within each dimension (at the end of the chapter). See Figure 22 above for a visual of how the various cross-cutting dimensions fit together as components within a process of youth pathway construction.

In each section I discuss what each dimension is, and then what the youth practices are for navigating within or leveraging those dimensions towards their desired STEM pathway construction.

The World as It Is

This is a study on youth who seek futures with STEM and who are actively working towards those futures in their lives. These youth live and construct pathways within the context of the world around them. The ways in which they view this world and negotiate with it or navigate through it affects how they experience life and work towards their futures within it. But they are not the only actors or forces moving in that world. In discussing the world as it is, I note that the structural and institutionalized dimensions of culture have been wielded by those in power to maintain inequities across race, class and gender. In this study, the ways in which external forces of power structured the world for young people profoundly affected their experiences of it and their ways of navigating it (Freire, 2007), shaping the possibilities youth had to author STEM pathways. This findings discussion begins by exploring and describing that world, as youth in this study have experienced it, in relation to their STEM pathways.

As I describe in findings below, the terrains that make up *the world as it is* emerged along three dimensions: *resources*, *space*, and *time*. These dimensions structured the terrain on which youth in this study described their pathway building, in that they provided the material and experiential matter to be manipulated and leveraged by people moving across that terrain. For example, terrains included *resources* of STEM learning support like books, teachers, mentors, classmates, family and friends, laptops, phones, websites, and even doctor visits. They included *spatial structures* of STEM learning life like homes, schools, afterschool programs, a science museum, neighborhoods, walks to friends' houses, buses and, and family trips to stores. They included *temporal structures* like school and scholarship requirement deadlines, afterschool program open hours, and free time alone in bedrooms and backyards to daydream, explore, and plan.

These three dimensions of life structure the locations, events, relationships, interactions, and opportunities that youth enter and navigate through as they seek to construct their present and desired futures. It is this collection of framing structures that the youth in this study who make up and move along pathways seek to control (e.g., youth practices to leverage time spent out of school with STEM towards pathway recognition).

I have observed, across the cases, that *resources*, *space*, and *time* are the *currencies* of the youths' pathways. By this I mean that control of those currencies – how they are invested, by whom and for what purposes – shapes how they may be directed toward youths' opportunities to construct pathways and in what ways (e.g., as a school district can determine how much *time* teachers and students invest during the day in science content and practice).

Beyond currency, these framing structures are also what make pathways *tangible*, as they make up the world as it is (and as it is experienced by youth). Resources are the objects, ideas, and people one interacts with; space is the intersection of coordinates that locate such interaction in the experienced reality (whether physical or virtual/imagined spaces of experienced reality); and time is the measure of moments that host and locate such interaction throughout a life.

Resources. Youth in this study described STEM resources as both components of and building tools for STEM pathway power. These could include materials, relationships, and ideas that populated their pathways as components ready to be navigated and leveraged by youth. How they engaged with resources, and how others made resources accessible to them, helped to determine or enhance their opportunities for conducting STEM pathway work (Hand, Penuel, & Gutierrez, 2012). Many types of traditionally recognized STEM resources were inequitably distributed and mediated by unjust power structures that severely constrained youth access, echoing critiques on structural inequities constraining opportunities to learn in STEM (Tate, 2001). This included physical objects (e.g., high-speed laptops with high-speed Wi-fi, microscopes, and telescopes), social and institutional connections (e.g., a relative who runs a chemical company or research lab, membership at a science center), and additional forms of virtual or symbolic science capital (e.g., knowledge of internship opportunities). Negotiating access to traditionally recognized STEM resources such as the ones listed above challenged youth to navigate structures that sought to either give or take power depending on how the youth were coded and categorized within such varied and intersecting contexts. This was often a dangerous and dehumanizing challenge structured by zero-sum competition, racism, sexism, and static cultural reproduction. Youth thus revealed differential access to such traditional resources within different and intersecting contexts. Rather than remain limited to inequitable resource availability, however, youth in this study worked to co-create and leverage untraditional STEM resources in creative and agentic ways.

Navigating and leveraging untraditional physical STEM resources. Youth navigated resources by recognizing the wide diversity of resources that could be related to STEM. A resource becomes a STEM resource when people name, legitimize, and leverage it as such (e.g., Gonsalves, Rahm, & Carvalho, 2013). Youth in this study demonstrated through their portfolio data and narratives that a wide variety of resources could be considered STEM pathway-relevant. They called for and used broader resource definitions to better acknowledge this diversity. Their lived experiences in the world contained a wealth of valuable resources to be leveraged and centered in STEM learning and practice, challenging power-mediated views of STEM learning that assume youth enter formal learning spaces with ignorance and deficits and that (predominantly White) teachers and other adults are gatekeepers of the only legitimate STEM knowledge and experience (Gutiérrez et al., 2017). I am particularly interested in those resources that youth leveraged that might not be considered a traditional STEM resource, and in how and why this mattered in gaining access to STEM on their own terms.

Keke, for example, was unsatisfied with formal STEM learning resources, so she turned family doctor visits into extensive medical research trips. She figured that she would need as many different types of learning resources as possible to support her desired pathway as a medical professional. She also knew that pamphlets at doctor's offices were connected to medical institutions' wealth of informational resources. Keke developed a hack to access medical science learning resources through "taking them all" at doctor visits, and carefully reading through them as medical science educational texts. She hacked the structures that were accessible to her in dimensions of patient care and healthcare consumerism/marketing.

Pamphlets were only starting points. From there, she Google-searched terms she did not understand in the pamphlets. Next, she spent hours upon hours reading WebMD and Wikipedia entries about her pamphlets' medical diagnoses, related symptoms, and potential complications that disturbed and fascinated her. Often, this moved fluidly into clicks and swipes on YouTube and other media sites that offered her images and recordings of ailments and procedures. She folded these documentation sources back into her developing case studies of both the human body, and the progress and practice of sciences and technologies for understanding and supporting it.

Keke argued for considering and officially recognizing her out-of-school activities and informational materials as legitimate STEM resources. She wanted to be able to leverage them for movement in formal and more powerful spaces of STEM learning and practice. Her decision to engage in pathway portfolio construction was driven by her desire to get this recognition, as a step towards receiving greater support and enhanced pathway movement. She knew that ownership of STEM resources was a form and use of power, and she wanted that power acknowledged by others.

Jazmyn leveraged untraditional STEM resources for positive change in traditional structures of STEM engagement when she asked for permission to take maker resources from her Afterschool STEM Program's makerspace. She wanted to create a handheld fan prototype, with the goal of personally using it in her un-air-conditioned school classroom. This was not related to a school lesson or suggested by a teacher; it was simply her creative expression of everyday engagement in maker practices with STEM to solve a personal problem that happened to occur in a formal educational space. Afterschool mentors recognized her legitimacy to do so and supported her resource-leveraging efforts across space by telling her she could take the craft and wire materials away with her. This resulted in her gaining recognition in her school classroom as an advanced circuitry expert, leading to peers requesting she make them fans as well.

Sincere also drew from his out-of-school lived experiences as resources to inform his in-school learning. This included building a bonfire with his older cousin and conversations about life and lifestyles with his electric company-employed aunt. He also explained that his afterschool engagement in making light-up crafts with LED lights moved him past his peers during a school project:

> Like, I had a school project and I had to connect a lightbulb to two batteries. My experiment worked and the lightbulb lit up, but the light bulb burnt out because I used a 9-volt battery. But I found a 6-volt battery and connected it, and it survived until I got to school. I shared my experience and how I did it and how it was related to science. Some kids asked, what did it have to do with science. I told them because of the electricity I was trying to put into the bulb to light up. I couldn't just make it.

In stating "I couldn't just make it," Sincere underlined his argument that he held a deeper understanding of circuit needs and design constraints than his school peers. He had developed expertise in circuity design and voltage calculations through a unit on electric art he had just completed afterschool, and he mobilized that expertise to enhance his engagement in his school project's circuit construction challenge. This was not simple project completion for a grade. He understood the concepts behind it that made it work. His mobilization of that understanding gave him the power to create and design in more informed and evidence-based ways, drawing from his ever-developing knowledge and practice across multiple different spaces in STEM.

Navigating and leveraging untraditional social and symbolic STEM resources. Untraditional resources were accessed by youth not only to create spaces for doing STEM, but to do so (and to talk about doing so) in ways that mattered to them as Youth of Color. Like the youth in Taylor and Hall's (2013) study who counter-mapped their neighborhood, the youth in this study leveraged a variety of resources across their life spaces to challenge dominant narratives about youth mobilities and to reinscribe their presence in a power-mediated world that often overlooked their critical mobility practices. Their descriptions of how they defined and leveraged diverse resources for STEM pathway construction pushed back against the racialized ways in which Youth of Color are often assumed to navigate spaces and resources of their communities.

For example, like Keke, José was determined to identify and gather up "every resource I can" to support his STEM pathway efforts. Ultimately, he explained, this work was much more enjoyable and effective as a joint effort. José sought STEM pathway movement through collaborative layering processes in which other people's ideas both informed and built off of his own. He liked the feeling of collective movement forward, but he also acknowledged it as a superior strategy towards his personally desired pathway movement. For him, this meant that people, their ideas, and their supportive teamwork, were his STEM pathway's most important resources:

> Other people's ideas help out with mine. Different people help me as in teamwork. In teamwork you use other people's ideas to help out with your own. And you give them a

> lot of credit too. Teamwork's most important because everyone's helping out with your work… and everyone gets credit. Everyone is appreciated for working. It's even and it's fair. It's important to me because it's fair. All you need is smarts, education, hard work, and teamwork. And people that have your back. People are important because they help me out and they help me learn too…

In this quote, José unpacked why teamwork held so much power as a resource for his STEM pathway efforts. Teamwork was not just about a feeling of community. It was about the feeling of protection against failure or danger that came with that community, the fact that trusted others could watch "your back." It was about increasing your own informational and skill-building resources, because you could find and access assistance when needed to enhance ideas or solve problems. For example, he explained that his YouTube channel project was a team effort even though he led that effort: "It was some my idea, but *we* made it [my emphasis]." Teamwork was also about fairness and justice, because recognition ("credit") and appreciation is democratized.

To José, resources could be expanded through their use, but also through their sharing. José hoped to multiply his own STEM pathway resources through a justice-seeking structure of teamwork with others. To him, this was a more justice-oriented way to think about and do work in the world with STEM. It was also a guarantee of gaining power. He explained, "It's all teamwork that has the best power… I [think] of power like in strength, and the best strength is teamwork and friendship and trust. Because we work together." José's building and sharing of resources were acts of building and sharing power for stronger pathways with STEM.

For all youth in this study, other people prominently featured in their descriptions of pathway supports. People and communities were named as STEM resources when they helped and cared about the youth who were building pathways. Jazmyn's mom's friends, for example, commissioned design work from her, via her mom's social media account. She saw their support of her work as accelerating her learning in tech-informed art and engineering design.

Beyond ideas related to people, youth in this study discussed a variety of symbolic STEM pathway resources. These included phenomena such as emotions, self-knowledge, and imaginative relationships with collective knowledge. Sincere evidenced self-knowledge as a STEM resource, for example, when he used his developing understanding of his social power and skills as a resource to restructure his afterschool STEM program's boundaries. José also demonstrated this when he called upon different sides of himself to handle different types of interactions in school. Furthermore, Keke's imaginative relationship with Wikipedia as a virtual mentor and friend (see the table below) opened up new ways for us to consider and discuss interactions between youth and resources as creative strategy for navigating power-mediated STEM learning. She wanted to talk more about her STEM learning, so she literally talked to Wikipedia as a symbolic conduit of STEM knowledge curated and made public by a world full of knowledgeable others. She separated this from merely thinking out loud while reading a Wikipedia article, explaining her constructed relationship with the website as one between "friends."

Pathway work is resource use work. Using resources is a central youth act of pathway construction. In the table below (Table 3), youth examples demonstrate resource uses as wide as their varying definitions.

Table 3: Examples of untraditional STEM pathway resources youth identified and used

Youth-Defined "STEM Resources"		Example of Youth Uses of STEM Resources
Untraditional physical STEM resources	Rides to school, work, and home in a city bus system	Amara and Keke re-designed these shared resources in order to share power with other riders in their city, while building STEM expertise, through their transportation heating project.
	YouTube	Amara and Keke watched surgeries on YouTube, describing this as medical research for possible futures.
	Fiction chapter books as peaceful protest tools	When school STEM classes were too boring to bear, Amara pulled out an unrelated book and began reading silently in view of her teacher, as a silent protest against ineffective spaces limiting her learning.
	Food in the belly	Amara explained that you can't learn on an empty stomach, because good, substantial meals are brain fuel.
	Doctor's office pamphlets	Keke developed a hack to access medical science learning resources through "taking them all" at doctor visits, and carefully reading through them as medical science educational texts.
Untraditional social and symbolic STEM resources	Parents' worldviews about life	José explained that his mom instilled a perspective in him that helped him understand his STEM pathway as a serious step-by-step challenge: "If I was raised any different, not to be the best and stuff, I wouldn't be in [STEM Program] because I would just be around playing."
	Helping others through mentoring	Jazmyn expanded STEM resources for herself by sharing them within community, through co-creating the Mentors-in-Training (MIT) program.
	Trust in others	José explained that a STEM pathway required "people that have your back" in order to reach your dreams.
	Other people's ideas	"You use other people's ideas to help out with your own," José explained. "I wouldn't have been able to come up with some of those ideas by myself."
	Family connections	Jazmyn helped her great-grandmother every day after school, in the kitchen of their community center. This gave Jazmyn skills for a hybrid career, and institutional capital that got her admitted to the STEM program one year early. Her mom also broadcasted her STEM achievements online to friends and family, who offered her support.
	Imagined/symbolic relationships with virtual intelligence	"Wikipedia and I are friends," Keke explained. She described Wikipedia as a virtual mentor, stepping in with feedback and advice where physical mentors were absent.
	Knowledge of self as a social leader	Sincere leveraged knowledge of his own popularity to recruit friends into his STEM program as design work assistants
	A younger sibling's vulnerability and love	Sincere wanted to protect his sister, so he often snuck her into his STEM program to keep an eye on her. She became a vocal cheerleader and advocate for him in the program.

As described at the beginning of this dissertation, I set out to explore with youth how different practices and resources can support learners' critical mobilities towards enhanced opportunities for pathway construction. We discovered that within the pathway dimension of *resources*, youth were already involved in a variety of innovative-but-overlooked navigational practices to create their own opportunities for enhanced pathway construction (e.g., agentic appropriation of otherwise-defined non-STEM resources towards new forms of STEM pathway authorship). So, adult recognition of such youth practices could support those efforts by better positioning them to be centered in discourse and to be leveraged towards further opportunities in more powerful spaces.

Youth leveraged a variety of resources across their life spaces towards pathway development in ways that challenge dominant narratives about youth mobilities and capabilities in the world. Recognizing, supporting, and leveraging such resources presents a complex challenge for youth and the adults supporting them in their pathway efforts. This is a challenge to open up new pathway development possibilities through creatively resourcing imagination and future-oriented co-creation. This could support youth in reinscribing their presence in a power-mediated world that often overlooks their critical mobility practices (e.g., learning about an older brother's mobility practices to engage in engineering learning towards sibling social protection in pool tournaments could pivot towards powerful, whole-class hybrid dialogue on content knowledge application and more youth-relevant curriculum unit structuring).

Space. Youth in this study constructed STEM pathways within and across different spaces of their lives. They moved within and across combined and intersecting space-time configurations as they engaged in these efforts (Leander, Phillips, & Taylor, 2010), but our co-analysis revealed some separately specific ways in which youth directed their navigational efforts spatially and temporally, so I present the two cross-cutting themes in their own sections here. Spaces included physical locations such as classrooms, living rooms, and afterschool programs. They also included more abstract constructions of social space such as communities, friendship circles, and project teams. Some spaces were digital (e.g., Wikipedia and YouTube), and some were individually imagined (e.g., daydreams of the future with STEM). As youth entered different types of spaces, they came into contact with different structures of power mediating space that connected to different historical and cultural contexts of being. For example, teacher-dictated cultural norms in science class often called on white, masculine, and heteronormative discourses of power that challenged youth to confront and navigate symbolic violence and oppression in order to participate or get recognized as a participant in that space. Youth in this study shifted spaces as they answered such challenges, layering social practices with learning practices or opening boundaries between home and school learning, for example. This section will explore youth perspectives and discourses about their experiences of spaces they encountered as they worked towards their desired futures in STEM.

Power-mediated norms of STEM spaces. Youth in this study drew boundaries around different spaces of their lives where they engaged in STEM pathway work, through their practices and through their talk. They described how different spaces of STEM affected their power to move, act, and imagine in different ways, comparing norms and routines of practice as design features structuring their pathway actions (Hand, Penuel, & Gutierrez, 2012). Often, they called upon comparisons between the power-mediated norms of school-bounded STEM spaces and out-of-school STEM spaces to underline the importance of specific out-of-school spatial contexts for supporting their youth pathway development.

For example, Amara explained in her first pathway interview that she experienced some spaces in her STEM pathway as supportive and others as the complete opposite. In school STEM, she explained that the power-holders of that space (teachers, administrators, and teacher-favored students) set the cultural tone for her participation options in science. Those options were to either conform as best as possible to racialized and gendered narratives about what makes one a "good student" in science, or to risk confronting aggression from the power-holders (e.g., Nasir & Vakil, 2017). Even for Amara, a mostly-A student described by herself and her twin sister as exhibiting a "nerd" stereotype, middle school spaces contained a minefield of performance expectations that were structured by the people who had power in that space. As Amara described it, those power-holders never included her.

Her school's power-sanctioned repertoires of practice and talk included White teachers' microaggressions against her and other Youth of Color (e.g., she shared a story in which a White female librarian taunted her and her classmates that they "wouldn't even be able to get a job at McDonalds") and prison-like interactions between students and police guards (e.g., she had witnessed a police "resource officer" physically grab a classmate during class in her seventh-grade year). Such glaring institutional norms of racism have continuously been documented within urban schools serving predominantly Youth of Color (Morris, 2005), resulting in a disproportionately negative impact on Youth of Color in terms of identity development and classroom engagement (Leath et al, 2019). For the youth in this study, these spatial norms drew rigid boundaries around available actions and connected identities-in-practice so that in that space, Amara the committed science learner hated school science. She explained that in school, science was boring and full of rules that appeared unjustly opaque and pointless. One example she shared, an item on her "worst moments in STEM" list, involved an assignment to fill out a worksheet about lab safety equipment after listening to a related lecture. She had hoped that following worksheet completion, she would get the opportunity to try on some real lab safety equipment and enter a lab equipped to safely participate in lab science practices. She was not granted any such opportunity during that unit, with her teacher citing concerns about her classmates' maturity levels. In the space of formal science education, her worthiness to participate in lab activities was determined by a power structure in which behavior management measures trumped opportunities to learn science like a scientist.

In her afterschool STEM program, conversely, Amara considered herself "a science and engineering major." Calling out this stark difference, Amara highlighted how the norms and power dynamics mediating those two different spaces made them feel so separate and opposite (e.g., in what they offered, what they allowed her to do, and who they allowed her to see herself as and get recognized as). This difference constrained her sense of power during the day throughout her middle school years. As she moved through school, she carried memories of former tears and experiences of current frustration with her, informing her perspectives on her school's powerful attempts to shut down her opportunities for development in STEM learning and practice.

Importantly, Amara added that this process of becoming in STEM was not possible in every out-of-school STEM learning space. In seeking the support she desired, Amara carefully observed how power dynamics played out as she moved through out-of-school learning opportunities. For example, she explained that she quit the robotics club for disappointing her with its inequitable power hierarchies between adults and youth and with its norms of handing out Lego instruction booklets for prescriptive step-following. She thought she was going to be able to build and program a robot of her imagination for local, specific use in her life, but instead she found an out-of-school space that reminded her “too much” of school. She wanted purposeful engagement in engineering and technology for personally meaningful outcomes. She also quit the Michigan Science Museum’s Youth Action Council program, because she did not see enough “older kids” in the space and received cues that the council was not going to be different enough from other areas in the museum that she felt were skewed more towards “little kids.” She liked the idea of taking on a STEM leadership role in the city, but not if it meant having to be publicly associated with a group of youth who did not share her interests or purposes for engaging. Across her life spaces, she sought out opportunities to conduct her STEM development processes on her own terms and no one else’s.

José, too, experienced spaces of practice in STEM, and opportunities for him to take up within those spaces of practice, strikingly different depending on their cultural expectations or norms. In school STEM classes, for example, José explained that he called upon “school José” to perform as was expected by the rules of play enacted (e.g., listen to authority quietly and do not cause disturbances in the routine). Jose’s categorization of spaces reflects those of youth in other studies which show how Youth of Color learn to racially categorize spaces such as schools, neighborhoods, and workplaces, such as the Black youth who learned to “adapt” in a predominantly White school in Ispa-Landa and Conwell’s (2015) study. He had to be a different José in spaces where academic achievement was posited upon White, middle class cultural norms (Ispa-Landa & Conwell, 2015; Leath, Mathews, Harrison, & Chavous, 2019).

In out-of-school STEM learning in his afterschool program and in his local science center’s Youth Action Council meetings, in comparison to school STEM spaces, he could become “José in engineering,” who was focused and hard-working with agency and expertise, surrounded by people “who actually understand me the most.” Depending on spatial context and the social and power dynamics that came with it, José explained that his repertoire of practices could vary from "procrastinating" and "snapping" back at peers who upset him, to working actively as a member of a team of peers who "listen to each other" and "keep on going until we succeed."

Physical constructions of STEM spaces. Youth learning in STEM is physically grounded in and constrained by the geographical locations where that learning occurs. What those locations include as learning space components, and how they operate in power matrices as sites of social relationships and material interaction, all influences youth access and opportunity within those physical sites (Leander, Phillips, & Taylor, 2010; Bright et al., 2013; Leander, 2002).

Confirming but going beyond her twin Amara's concerns about cultural norms and power abuses within their shared spatial boundaries of learning, Keke also critiqued frustrating physical architecture and missing physical components of spaces that impeded her efforts to learn STEM. The construction of her school hallway and stairway spaces, for example, often prolonged her journey from her eighth-grade lunch hour to post-lunch classes "two flights of stairs" away. This increased the amount of time she was exposed to embodied norms of being in school spaces that "perpetuates anti-Black discipline and represents behavioral responses to White femininity that may not align with Black girls' femininity and identification with school" (Hines-Datiri & Carter Andrews, 2017, p 4). Added to this was an administrative policy controlling access to different school spaces by student grade, so that "certain hallways and staircases you can't use at certain times." Based on Keke's first-floor locker location, her stairwell assignment made her walk to math class twice as long by forcing her into a long double-back route. She and her sister Amara's dependence on the bus to get to school also guaranteed them a disadvantage in their school's system of acceptable student behavior. “I’m late every day, because we ride the bus,” she explained. “I always used to be at level 1, but she [math teacher] bumped me down to level 2 just because of the bus,” a rubric difference that affected how she was positioned as a student and learner in her school STEM spaces.

José also emphasized the practical boundaries and components of physical spaces across his life as constraints on his pathway development desires. When listing his “places where I do, think about, or talk about STEM,” José explained that “I do not do STEM in a lot of places.” He mentioned his mother and brother’s work schedules as factors limiting their availability to take him to any informal learning spaces across his city. Every day after school, he took a free shuttle to his local community organization, where he participated in our STEM program. Then he either took the city bus or got a ride home from a program mentor. He often let himself into his family’s apartment and made his own dinner, and then watched TV alone. He sometimes had STEM-type wonderings about everyday phenomena he observed at home (e.g., considerations of angles and trajectories when throwing a piece of garbage in the kitchen trashcan), but he explained that he did not have an opportunity to share these thoughts with anyone else very often.

Practices for navigating spaces. As youth in this study gained understandings of spaces and power-mediated definitions of accepted practice and talk within different STEM spaces, they developed skills for critically navigating or challenging the differences they found across space (Gutiérrez et al., 2017). These skills supported their varied desires to move within and across STEM learning spaces in ways that supported their pathway efforts. There were three main strategies that emerged across youth in this study: a) keeping silent, b) imagining better future spaces, and c) lobbying adults for assistance.

Keeping silent. Sometimes, getting to the next step along their pathway forced youth to choose between vocally expressing themselves and fitting into the dominant cultural norms and histories of a STEM space. This happened most often in school STEM spaces, for youth in this study. Amara noted multiple times that teachers did not care about what she wanted from her education, so she put effort into quietly sitting through class as a listener, not a talker. She sharpened her focus on self-control to gain pathway movement through the "boring" spaces that demanded her silent agreement in order to pass through those spaces unscathed, explaining: "I was "the good kid." I knew that if I just keep good grades in class then when I was out of class I can be more open and reckless with my friends."

Amara's strategy did allow for some targeted silent protests, however. A common one of hers was to take out a fiction book from her backpack and start reading it at her desk during class: "I read in front, so the teacher knew I was bored." It was assertive resistance, bold and decisive, but it was opposition still technically within the boundaries of her school spaces' expectations for muted class behavior. It was an expertly measured confrontation with power. It was also an emotional escape valve for her, an action that allowed her to break free, if only for a moment, from the confining boundaries of how she was allowed to be and behave in her formal educational spaces.

The demands of silence and compliance on Youth of Color in school are well documented in the literature (e.g., Fordham, 1993; Taliaferro-Baszile, 2006; Varelas, Tucker-Raymond, & Richards, 2015; etc.), but even compliance is a losing game. For example, Nyachae (2016) explained that "those who are silent and conform are welcomed" for their ability "to meet a White middle-class normative," and this is especially true for Black girls (pp. 789, 798). Yet when they adhere to such demands to shut off the self, Youth of Color are not guaranteed any lasting benefits from the inequitable systems that purport to protect and nurture them.

Keke and José also used a keep-silent approach to survive school cultural expectations in STEM, but they knew all-to-well the limits of such a self-limiting approach, as neither could stay under teacher disciplinary radars forever. Both Keke and José had mentioned feeling pressured to control or close down their thoughts in spaces where it was clear that their opinions and personalities were not welcomed. Teachers placed more explicit pressure on them to change and control their expressive personalities than they did on teacher-celebrated Sincere and Jazmyn, who more consistently delivered teacher-pleasing performances of friendly acquiescence to behavioral policing.

José described his limit-reaching moments as “snapping” moments in which he released built-up feelings of anger and frustration on whomever had unjustly targeted and disrespected him. It was not enough to accept the ever-heavier pile of injustices experienced in school, including racist and classist aggressions from both teachers and peers. José and Keke had both described feeling targeted, bullied, and/or ignored from multiple different sources in their school classes. When this happened in classes they “actually cared about,” Keke explained, it hurt even more and was more difficult to hold in. These types of emotional boiling points often resulted in detentions and suspensions for Keke and José.

Imagining better future spaces. Where traditions of power-mediated learning structures fail, imagination is required to support youth more equitably in navigating structures, as well as to support youth in asserting their agency towards transformative outcomes (Gutiérrez & Calabrese Barton, 2015). When breaking out of failing structures was inaccessible in their present, youth in this study found that re-imagining future space for learning and practice supported their efforts to construct STEM pathways towards those desired futures.

Like Keke, construction and impacts of physical space also featured in José's description of his STEM pathway desires for his future. José explained that he sometimes liked to sketch out imagined future spaces as a strategy to survive the disappointments of the spaces he experienced in his day-to-day life. His future office, for example, the STEM-rich space he constructed in his daydreams while procrastinating participation in school science spaces, would be a space of natural light, leaves, solar panels, protection, and strength. It would be located high up at penthouse level and surrounded by "indestructible glass," separating him from danger or destruction. It would not be too high, however, to benefit from being fully surrounded by "a lot of trees around it" with ample leaves working happily "to absorb carbon dioxide and release oxygen." This biomimicry-informed space would also be loaded with the latest technological resources including a "solar-powered supercomputer" to assist his life's work as "the world's greatest hacker-tracker" or "bionics master." It would be everything he wished for in a space and in a brighter future. For José, imagining the future also involved designing the imagined spaces in which this future would occur.

Amara and Keke also often imagined what their future careers in STEM would look like and include. While they both drew impressions of these spaces in response to "draw you in the future" protocol items in pathway interviews, their more common futuring involved words and numbers through detailed list-making and Wikipedia research. They used iPhone documents apps to chart out likely required coursework in different undergraduate pre-medical school programs that they were considering applying to. They researched job descriptions and required qualifications. They also looked up tuition rates and funding options that could support their pathway-furthering efforts. They continued to navigate within school spaces to not miss out on the capital they mediated (e.g., seeking AP class entry and high grades). Meanwhile, their detailed and plan-oriented imaginings helped them see the bigger worlds outside of those spaces while also preparing them for additional school spaces yet to be confronted.

Lobbying adults for assistance. Developing relationships with adults in power was one important strategy youth leveraged for securing support for their desired pathway construction. Where spatial or material structures fail, social structures within matrices of power can be pivoted towards young people's desired outcomes if powerful adults can be transformed into trusted allies (e.g., Rivera Maulucci, Brotman, & Fain, 2015). So, where they could, youth leveraged the social relationships they found within different spaces, especially positive relationships with trusted power-wielding adults, to form pathway "support teams." These coalitions could help youth to access more fluid movement across spatial structures of cultural practice and power. Support from such institutional brokers aided youth STEM pathway efforts within and across the spaces where supporters held power.

For example, as described in Jazmyn's pathway narrative, Granny's lobbying efforts resulted in Jazmyn's acceptance into her afterschool STEM program one year earlier than her peers. In another example, in response to her advanced performance scores in her sixth-grade math class, her teacher contacted her mother, and they decided together to move her down the hall to the eighth-grade math room that year. This exposed her to new mathematic concepts and practices. It also exposed her to a new form of bullying from an eighth-grader sitting behind Jazmyn's new desk who would kick her when she answered math questions correctly. She described this student as "jealous because they're slow" in a nod to her developing understanding of her increasing power to move quickly across STEM learning spaces.

While Jazmyn found a “support team” readily available to listen to her needs across STEM spaces, Sincere took action to seek out individual adults as key players he could influence as he publicly critiqued and reimagined current spaces around him in STEM. In his pathway interviews, he described his STEM learning spaces as structures he could change through negotiation with people in power. As I was one of those people, he reminded me how he had convinced me to shift the policies maintaining boundaries of socialization and practice in our afterschool STEM program. His success in this effort changed what roles and actions were available to both him and his peers in out-of-school STEM. Sincere’s social boundaries had already crossed organically into STEM learning boundaries, because his friendships connected across from school to his afterschool STEM program. He expanded on these connections across space by recruiting friends, and encouraging those friends to recruit friends, into STEM work groups with him. He also worked to open up opportunities for other youth connecting efforts in afterschool STEM.

Sincere lobbied adult mentors to both blur program boundaries and expand openings into the space. First, he began a practice of purposefully inviting a male mentor to join him and his peers on the basketball court before the program opened. When playtime cut into STEM program time, he used the mentor’s presence with him on the court as leverage to avoid scolding and ensure his membership stability in the program. Second, while some of his recruited friends and friends-of-friends remained in the STEM program, others visited more sporadically and only when Sincere was in the room. Their sporadic type of membership was not initially legitimized within the STEM program, because program mentors preferred a greater commitment from youth members and more sustained engagement with program content. Sincere asked for this to officially change. He wanted his preference of a wide-open-door policy to become more explicitly sanctioned and encouraged program-wide.

Recognizing this policy's importance to Sincere and his friends (who did not want to fully give up their investments in other afterschool activities) was a turning point for Sincere's STEM pathway. He wanted access to a greater variety of social supports to structure his afterschool STEM work more flexibly, and in ways more representative of the diverse spaces and communities of practice he valued and engaged with. Sincere sought porosity for self-directed movement between these spaces, both for himself and for his community members. This supported his navigation and leveraging of a greater diversity of resources towards his desired STEM pathway work.

Sincere brought his support network of friends and classmates into his community organization's makerspace room to assist him in his STEM pathway construction. They moved into this new space and joined him in his efforts, both to share their support with him and to receive his reciprocal support as a respected ambassador of that new space of power. They wanted access, and he fought for them to get it. In this way, Sincere became a leader and representative for a large number of youth STEM pathways besides his own.

Table 4: Examples of ways youth interacted with STEM spaces in their pathways

Physical STEM Learning Spaces	**Power-mediated Norms within Them**	**Some Physical Features Discussed**	**How Youth Understood and Navigated Them**
School STEM spaces	- Teacher power-holding (not power-sharing) - Listening (not talking) - Following (not leading or challenging)	- Long journeys down hallways and up stairs - Sitting bored	- Keeping silent (but sometimes "snapping") - Imagining better future spaces
Afterschool STEM Program within Michigan Community Center	- Sharing and challenging forms of power through STEM-rich maker engagement - Political engagement through STEM recognized as legitimate	- Walking distance but not considered by adults to be safe to walk to alone - Youth-designed with lounge and collaborative work spaces	- This was described as a STEM homespace by youth in this study, where they developed STEM learning and practice foundations out of school (Hooks, 1990) - Lobbying adults for access and opportunities assistance

Table 4: (cont'd)

Michigan Science Museum's makerspace	- Sharing forms of power through STEM-rich maker engagement	- Not walkable - Youth-designed preteen space within larger power-mediated "little kids" spaces	- José and Jazmyn gained recognition for expertise they moved there from their Community Center's makerspace.
Michigan Science Museum's Youth Action Council	- Sharing and challenging forms of power through engagement - Membership boundaries skewed young	- Conference room meetings with whiteboards	- Jazmyn and José joined this leadership group to voice their concerns about public access to STEM resources. - Amara quit this group because she did not see it as productive for her pathway.
Additional neighborhood community center (Sincere)	- Locally grounded membership and ownership	- Walking distance, safe with family and neighbors	- Sincere explained that these events expanded his terrain of available spaces across which he conducted his pathway work.
University summer program	- Accessing institutional connections to expanded scales of power (reaching from high school to access college forms of power, like dorm living and professor relationships)	- University lab rooms and equipment (impressive enough for Keke to take selfies with)	- Keke, Amara, and Jazmyn explained that their participation in the program expanded their exposure to STEM professional practice and increased their awareness of possible college STEM pathways.

Time. Time was a serious and consequential pathway structure for youth in this study. First, time could act as a powerful source of risk. Youth held a grave understanding in this study that time could act with its own agency, void of any complicating human interference. It was a dangerous force in its own right, working against pathway efforts (e.g., there are a limited number of years to live, so there is a limited amount of time to make decisions that affect one's future opportunities with STEM). It could also be wielded by more powerful adults as a weapon against youth pathway efforts. Therefore, youth understandings of time often carried with them understandings of pathway danger.

Youth also experienced time as a helpful structure supporting pathway work (e.g., in how youth in this study leveraged their out-of-school time towards STEM learning goals that differed from school). Beyond existing as a structure, youth in this study engaged in practices to leverage their navigations of time towards supporting their pathway efforts in STEM (e.g., for gaining recognition, and as a helpful reimagining tool). In this study, time was a pathway structure always present and always framing action, but also always dependent on context and perspective for definition.

Time as pathway constraint. Time constrained youth understandings of pathway possibilities and efforts to explore those possibilities. One cause of its impact as a constraint was that it was often mediated by other people who held significant power over youth (e.g., teachers administering timed tests) and could therefore become an active adult weapon against youth pathway efforts. For José, for example, time was a measure of seniority that limited his options for becoming an Afterschool STEM Program mentor as a seventh-grader. Time also framed his desires for a STEM pathway that allowed him to die as a revered STEM “legend.” For Keke and Amara, time framed their fears of aging out of their supportive youth programming afterschool and their decision to extend their connections to that space through new teen-specific roles. Amara also connected her worries about “wasting her time” in pointless class lectures to her understanding that she only had a specific number of years to become a doctor, so urgency was implied everywhere across her STEM pathway. Sincere’s understanding of time’s constraints increased his feeling of urgency to advance his younger sister’s STEM pathway work through tutoring her at night. Jazmyn’s time constraints were imposed by the large amount of adults who had filled her afterschool and weekend hours with responsibilities.

Time as pathway support structure. As youth worked to construct STEM pathways, they used time as a navigational and building tool. Specific events in time, for example, offered pockets of opportunity and possibility for youth to explore their pathways in new ways (e.g., a community presentation event as a publicly understood appropriate time for positioning and recognition work). Time also offered youth a linear framework for arguing their legitimacy in STEM by demonstrating their amount of time in STEM.

This was an important STEM resource for Keke throughout middle school, for example, because she understood and discussed the amount of time she had committed to STEM in her afterschool program and at home as evidence of her legitimate presence as someone who belonged in STEM learning and practice. In another example, Jazmyn understood the amount of time she had spent throughout her life at her Michigan Community Center as evidence of her popularity in the Center and with adults working there, a resource she leveraged for early entry to the Afterschool STEM program and continued mentorship by multiple adults there.

Practices to leverage time. Time in adequate quantity and quality has been widely researched as a crucial resource for youth learning and development (Tate, 2001). In this study, youth consciously leveraged time as a contextual and flexible STEM pathway-making tool, in ways that complicate and expand traditional understandings of time in youth learning and development. This was evidenced in the diversity of ways youth experienced time through participation in practices and in how youth used time as a resource (e.g., within discourse with others). Temporal context could be defined by pathway structures, in that space, power, and other pathway components affected how time is experienced and used. While it was a directional dimension, time with learning and practice could be understood, traversed, and leveraged differently depending on youth contexts and needs.

Reimagining time. Youth also practiced imagined movement through time along STEM pathways just as much as they experienced temporal movement in real life. Prior research has documented the importance of current practice for facilitating imagined futures (e.g., Tan, Calabrese Barton, Kang, & O'Neill, 2013). In this study, a different directional relationship also occurred whereby imagined futures were important tools for surviving and navigating constraints placed upon current practice. When on-the-ground actions went unnoticed or unleveraged, virtual or imagined futuring work gained importance as a way to regain a sense of agency and ability. Mental time travel, in other words, helped when one desired to transcend current constraints on pathway mobility.

Compared to Jazmyn, for example, José and Sincere drew from a smaller network and leaned more on their own imagination for exploring possible futures. José demonstrated this through his descriptions of stress related to scholarship deadlines and his practice of picturing himself twenty years further along his pathway. A multi-decade time jump opened up the possibilities of what his future could look like and include, in that perhaps anything could still happen for him. In reality, he was rushing to raise his grades, but through his imagination, he was able to realize that on a broader scale, there was time yet before his future became more concrete and he had opportunities still to explore what he wanted that future to be. For José, time was implicated in constraints of asserting his own agentic development. He needed to expand time in his mind in order to see the agency he still had to make his own life decisions with STEM. The distance between present and future time expanded José's thoughts of what could be possible. Creating an imaginative future life (e.g., with descriptions of engaging in future-oriented areas of ever-evolving possibility like bionics and genetic engineering) helped him to develop a more hopeful perspective on his present.

Building power with time. Youth used the power of out-of-school time to expand possibilities in STEM (Calabrese Barton et al., 2013). They used time to demonstrate their own power over their pathways, for example, by showing how they used and invested afterschool time towards directing STEM pathway movement. This was possible in part because out-of-school time was flexible in a way that time-related experiences and discourse in schooling were not. In school, time could feel static, cemented in place, and always linear. But out of school, youth could move back and forth along positions in time, and they could chunk time in ways that were helpful. For example, Keke used time to demonstrate how much learning and practice she had accomplished as she built up her knowledge and skills in STEM, explaining her understanding of her own advancement as accelerated temporal movement: "I do things that other people don't do… Everything I've done so far, people don't usually start this until their 20s." During afterschool hours, she was willing to work beyond what she saw as being commonly expected of her and her preteen peers in the present, in order to access practice and development not commonly open to her and her peers until later in life. This gave her a "head start" along her STEM pathway which she leveraged in her assertion that she was "more advanced" and "ahead of the game."

Keke's temporal movement was also STEM-status positioning work. It started with recognizing herself as "behind" in school science. Getting to a status of being "more advanced [and] ahead of the game" required a time investment in STEM participation and knowledge/skill expertise development. Her awareness and self-recognition of development was recognition of movement over time through pathway-related identity work. She put purposeful effort into restructuring her access to STEM resources. Over time, she began to witness her own movement towards expertise and an "advanced" positioning in STEM. This allowed for a change, over time, in her STEM positionality and power.

Table 5: Examples of ways youth navigated and worked with time

Types of Time	Some Youth Practices	Interactions with STEM Pathway Efforts
Pathway structure of constraint	- Understanding urgency and acting quickly towards goals	- José could not gain the public recognition he saw teen STEM Program mentors receive, when he was still a seventh-grade student - Sincere's basketball time overlapped with STEM Program sessions, causing tension that required negotiation with adults
Pathway structure of support	- Understanding time spent in STEM as evidence of legitimacy in STEM	- Keke and Amara used their out-of-school time to create a part-time job for themselves that also supported their STEM pathways - Jazmyn's years at the Center afforded her afterschool STEM capital, which got her into the Afterschool STEM program early
Resource for youth leveraging	- Reimagining time - Building power with time	- José used mental time travel in daydreams to reimagine his life as full of high-tech resources and happy STEM work spaces - Keke argued she was "ahead of the game" because she used her afterschool time for STEM advancement (compared to peers)

This dissertation sought to understand youth definitions of and relationships to space and time as dimensions in and through which youth constructed their desired pathways towards the future. We learned that youth experience and act with space and time in ways that stretch researchers' space-time theorizations by complicating boundaries of both and by intersecting their own needs and concerns related to power and positionalities through their purposeful STEM engagement practices, as detailed above. Space and time were experiential aspects of the pathway terrain, for example, but also power-mediated tools implicated in both structural problems and agentic solutions in complicated ways that demand further study.

Working Towards the World as It Could Be

In desiring and working towards and along pathways to their desired futures, youth seek to affect those structures of time, space, and resources that frame and help determine their present and desired futures. Some practices for navigating those structures were detailed in the first section of this chapter (e.g., leveraging time as a tool to demonstrate power through knowledge gained over time). The second layer of youth pathways are the means by which youth seek to control and change their world in more active and concrete ways that go beyond navigation. The five youth in this study not only worked to creatively navigate the world as it is;

they also sought to create the world as it could be. This continual effort to transform reality for the better is a crucial signature of humanity (Freire, 2007, p 92). The collection of constructs explored in this section—*purpose, re-seeing*, and *action*—were the tools that youth took up towards changing their realities. They recognized that the social reality in which they were seeking STEM pathways was created by human action and could also be transformed by human action (Freire, 2007, p 51). This section describes dimensions and components of their efforts at transformation.

Purpose. People always have reasons for doing things. In common usage, purpose carries a definition of deeper feeling and more sustained commitment to a particular cause for action compared to terms such as motivation or goal. Different from intrinsic motivational processes in learning (Deci & Ryan, 1985) and from the autonomous integrated regulation of extrinsic motivation (Ryan & Deci, 2000), youth in this study used a more sociocultural framing to define *purpose* as critically interwoven with and continuously re/formed in dynamic relationship with people and contexts that mattered to them and their communities. They used this definition of *purpose* to describe their commitments that drove them to engage in STEM learning and practice and to construct STEM pathways. Their sense of purpose centered their actions across space and time with an understanding of their efforts as grounded in contexts that mattered to them and to others they cared about.

Reaching their desired futures was one important purpose for overarching goal-setting. Youth also purposefully engaged in daily actions with STEM that connected to a complex context of desires beyond themselves and their individual future visions. When learning spaces supported, deepened, or expanded young people's purposes for entering them, their engagement in practices within those spaces gained traction. In this section I describe the different purposes youth held for STEM, and how these centered their actions and decisions in different ways, guiding and resourcing their pathways towards different futures.

Planning navigations across formal spaces. Youth in this study recognized their interests and took on efforts to pursue them in the present, in ways that connected to possible futures (Calabrese Barton et al., 2013). They sought to construct those futures in concrete ways, so they invested energy into purposefully planning out their STEM pathway construction efforts. Youth discussions around their explicit planning practices demonstrated their awareness of their multifaceted purposes for acting on their STEM pathways. These planning efforts looked different based on what resources and support structures were available.

School bounded and shaped some pathway planning efforts by constraining purposes in specific ways, always connected to a sense of urgency. For example, José's tangible steps along his STEM pathway took on more concrete shape as he chose to center his college scholarship. This purpose helped him to lay out and establish priorities based on understanding the rules implicitly connected to such a purpose. He had learned over time, for example, how to play the required game of winning desirable school grades. José knew that his future plans for gaining global recognition were constrained by his need for tuition support. Likewise, as he understood it, keeping his scholarship depended partly on his grades, so he focused more intently on securing the highest grades he could. Sometimes this meant missing his afterschool STEM program to invest more time on homework and extra credit assignments. Sometimes it meant bringing his homework into the makerspace to request extra adult help with his schoolwork. During this study, it also meant seeking out a tutor to raise his failing math grades. José's knowledge of his mom's sacrifices to pay this tutor added an additional layer of purpose (and pressure) to his quest to keep his scholarship. He wanted to succeed not only for himself, but for her: "It's important to me so I can impress my mom and stretch out for success."

In another example, Amara established next steps along her pathway from her understanding that school science learning was necessary for her planned medical science pathway. She had sketched out what was necessary to succeed in that pathway, and she was explicit about the importance of clearly understanding requirements to succeed (e.g., what classes were the most important to score highly in) in what she termed her "pathway to doctorhood." Despite this broader-scale sense of a future-oriented purpose, however, Amara explained that her chosen pathway brought her daily challenges. Unlike José, the requirement of high grades, for example, was not enough purpose to guarantee her full commitment and engagement in the smaller steps along her pathway, including everyday challenges like "boring" class discussions and assignments. She demanded more of what I call a "present" purpose to school engagement besides gaining future entry to her next pathway stage via high grades. She wanted to fully engage her mind in STEM learning that was more deeply connected to her desires to transform her community's landscape of opportunities, like the learning she engaged in during her afterschool hours. She argued that she deserved better opportunities for learning, for example, through concrete action that could produce immediate and locally felt impacts in the world outside of her school's building (e.g., using electrical and thermodynamic learning to engineer a heating system for the bus stops she used every day during winters).

Importantly, the youth in this study also looked outside of school to gain the purposeful engagement in learning they sought. They searched out alternative pathways for more meaningful engagement with STEM learning and practice, when traditional pathways were not purposeful enough (e.g., when Keke developed a "science person" identity-in-practice in our afterschool program that she could not access in school). There, they used their STEM learning and practice as tools for changing inequitable structures in the world and for seeking new positionings and identities-in-practice in the world.

Drawing strength from family and community. Young people's purposeful planning framed and strengthened their movement along STEM pathways, as a driving organizational structure from which their actions and commitments took shape. For the youth in this study, drawing from community and family experiences, histories, and resources strengthened this effort by grounding that engagement in contexts that mattered to them (Gutiérrez et al., 2017). Sincere, for example, committed to a long-term engineering design project to improve his younger sister's community of play. He explained that he pushed through design frustrations because he had a purpose in mind connected to a) his sister's desire to be included in the afterschool culture of gameplay, and b) his desired development of blueprinting and construction skills towards a future in architectural engineering. Keke, too, pushed through frustrations with her anti-attack coat's alarm trigger testing because of her commitment to working towards a STEM pathway out of school in which her STEM engagement would help others (e.g., girls with defensive clothing, children with pediatrics, etc.). This was action to honor and amplify the voices of community perspectives, desires, needs, challenges, and demands. In a third example, Keke and Amara's mom was a city bus driver, so they had expertise on commuters' experiences that grounded their shared STEM engagement with a sense of purpose to create change for their city's transportation system and its riders. They explained that they wanted to make their community members feel welcomed and desired by systems of power they moved within and across, just as they were seeking to be desired by traditional communities of practice in STEM (e.g., higher mathematic study communities, medical schools, etc.). This included the public transportation system that controlled their mobility, and the broader systems of public services that affected their quality of life in real, consequential, tangible, viscerally felt, and deeply personal ways. Their lived experiences within such systems of power committed them to honoring and alleviating their fellow community members' experiences in those same systems.

Youth in this study demonstrated that when they could connect (and were supported in connecting) purposes for engaging in STEM to people and places they cared about in authentic ways, engagement in science strengthened. For example, Jazmyn's desire to inspire younger children to explore STEM led to her purposeful dedication to creating electrical science curriculum to excite and surprise. She altered her form of STEM engagement to serve this centering purpose.

The tension of structural constraints heightened the urgency of purpose. The lived experiences of youth in this study mattered in the present and fueled action towards the future. The urgency of purposes that helped drive engagement in STEM learning and practice was connected to and structured by the constraints of life structures that limited access and opportunities by limiting resources, space, and time. For example, youth recognized purposeless learning as detrimental to their pathway movement because it wasted their time. They wanted purposeful movement towards their futures, and their recognition of structural constraints informed their understandings of their pathway efforts' purposes (Freire, 2007).

For example, Sincere, a self-described future owner of his own architectural engineering firm, wanted to build the skills and knowledge needed to control his own future as an architectural engineer. He joined the Afterschool STEM Program to support movement along his pathway: "It kind of helps me be an architectural engineer… because we get to build things and discuss different things and we get to work together on how we want things to be." But he did not want to sacrifice his opportunity for basketball engagement, especially when he needed it for emotional regulation after a bad day at school. This tension he experienced between the coeval opportunities at his afterschool Community Center provided him with an urgent purpose to work towards reconstructing his STEM learning schedule in negotiation with me and the Afterschool STEM Program.

Amara also defined her STEM engagement through a centering of purpose that derived urgency from its rareness of opportunity. She did not find school learning to be grounded in immediate, tangible purposes. Purposeful learning was necessary for Amara to engage, and she explained that the "kaboom science" her school spaces offered (e.g., labs and demonstrations removed from real life contexts) didn't go far enough towards exciting her interest. When such STEM learning could be defined as "pointless," Amara said that she and other youth she knew were less willing to engage because it insulted their intelligence and wasted their time and energy. But when she felt that her learning had concrete purpose (e.g., her afterschool engineering design project for community infrastructure change), she defined it as "not boring," especially when compared to school STEM learning that derived thinner purpose from grades.

Table 6: Examples of ways youth leveraged purpose towards pathway construction

Types of Purpose	**Purpose-Leveraging Pathway Practices**
Planning navigations across formal spaces	Amara's medical science pathway and José's scholarship desires influenced their efforts to conform to school grade expectations
Community and family contexts	- Daily rides alongside their city's commuters inspired Keke and Amara to design solutions to rider discomfort and danger - Jazmyn reimagined STEM teaching and learning designs to better serve younger peers
The tension of structural constraints heightened the urgency of purpose	Sincere's desire for basketball time drove his efforts to negotiate for more flexible scheduling of his STEM program time

Re-seeing. The youth in this study demonstrated a radical hope for both present and future change through their critical imaginations. I refer to this aspect of pathway authoring as re-seeing. The idea of re-seeing is grounded in Freire's idea of acting with love for oneself and for other humans through an effort to critically understand the problems and possibilities of reality in order to transform it (Freire, 2007, p 92). It is also an act of hope "to look out beyond the actual and the given" towards more diverse ways of seeing and thinking so that "alienation and fixity give way to participation and movement" (Greene, 1982, p 9). Youth in this study found ways to re-see the world when possibilities got opened up for them *in* that world to conduct that re-seeing, in equitable ways. This helped them to recreate the world together in partnership with others, by leveraging their belief in "the magic of what might be" in that world (Obama, 2018, p 420).

Critical redefining work. Youth in this study argued for new and more critically informed definitions of the world around them in order to gain recognition as legitimate STEM people in and across power-mediated spaces of learning and practice. This connects to the literature on counter-narratives as opportunities for Youth of Color to speak back against dominant narratives that discriminate against them by positing deficit discourse as reality (Solórzano & Yosso, 2002). Youth built upon this tradition to redefine pathway components across multiple positionings and towards transformative outcomes. Their redefinitions were engagement in radical dialogue to "name the world" in their vision and to encourage critical thinking about that world (Freire, 2007, pp. 88-92, 128). These efforts echoed Freire's (2007) argument that "it is in speaking their word that people, by naming the world, transform it" (p 88).

Youth critically redefined space and time during this study on their STEM pathways. By naming time at home or at an afterschool organization doing particular activities as time spent with STEM, for example, youth could argue for the legitimacy of their home and afterschool efforts as central to their STEM pathway work. Keke demonstrated this when she presented her pathway portfolio as an alternative yearbook. She framed her out-of-school STEM experiences as time spent learning, in much the same way as yearbooks archive learning and development from in-school time. She made this intention explicit by announcing to all viewers on her title slide, "Welcome to my year book!!!" Keke had not received many "A" grades throughout middle school, and especially not in science. At the same time, she sought recognition as a successful science learner who planned on continuing this success all the way into and through a prestigious medical program and pediatric residency. As someone for whom school time was not always full of recognition or validation, she used the idea of a school yearbook to frame her time with STEM outside of school as officially recognized and validated time with science learning. She called upon her personal, out-of-school time invested in STEM as a representational dimension that helped her efforts to change her public narrative with STEM. It supported her argument that regardless of school grades, she was a successful science learner, thinker, and doer throughout her middle school years. What she chose to detail in her yearbook, as compared to what her school's yearbook staff chose to recognize within the boundaries of school time, was to her a more accurate account of how she had invested and leveraged her learning time, and what it had yielded for her in terms of academic and personal growth with STEM. This practice allowed her to acknowledge and formally honor the investments she had made in her own intellectual growth over time, in publicly respected ways that her school structures had not.

Youth in this study also critically redefined power in STEM. As a part of his pathway portfolio construction, for example, José drew several different animé-styled abstract representations of his STEM pathway's components, including a representation of what science meant to him and what power meant to him in his pathway. These pictures explored themes of social justice and community collaboration, family love and friendships of trust. His representation of science was based on a ball of plasma depicted in animé cartoon Dragon Ball Z, his favorite show. In his version, multiple hands held an energy field together with teamwork, adding their own energy at the same time as they enjoyed access to the energy source themselves. The physical world, to José, was mediated by forces that could not be seen but could be shared, the most powerful of which were teamwork and friendship.

Recognizing more dimensionality. Youth in this study moved and worked through multiple dimensions as they constructed pathways to their futures with STEM. As they began to notice more layers of the world around them, it opened up new possibilities for that reality to be explored and leveraged (Engeström & Sannino, 2010). This was continually interwoven with but different in kind from redefining components of their world, as recognizing more dimensionality was less about critically arguing for counterdefinitions and more about discovering complexities around them that were always there. When youth took interest in seeing complexity across dimension, they enhanced their understandings of the world and their possibilities within it.

Sincere, for example, discovered that his sister could be more than a personal responsibility and symbolic inspiration for his STEM efforts; she could also become a tangible supporter and project assistant pushing his ideas and skills forward. This led him to describe his sister as a multidimensional force in his STEM pathway during this study. His developing understandings of her as a STEM resource for him layered atop additional roles and identities-in-practice she had occupied in his pathway. For example, she was a manifestation of the responsibility he felt towards younger children who sought futures with STEM, and a complex person in her own right. She looked up to him as a STEM role model, and he made her a welcomed member of the makerspace community, helping her to create her own multilayered presence in the room (e.g., as makerspace visitor with or without Sincere).

In another example, Jazmyn developed over time a more multilayered vision of herself as a person with STEM, as she realized that she could connect her artistic and cooking pursuits with her chemistry and engineering design pursuits in an integrated STEAM career. I witnessed this development across our pathway interview sessions together, as she wondered aloud about her future career decisions and as we looked up popular new STEAM careers online (e.g., during one session, we searched Google images with the terms "molecular gastronomy," "chemistry and food," "kinetic fashion," "wearable electronics," etc.). She described her concept of a future community center with multiple uses and spaces as a site for a future combining her interests into a more multidimensional career.

Through re-seeing practices of critical re-definition and recognizing more dimensions, youth leveraged their imagination to understand and represent the world in new ways. This enhanced their abilities to move across new dimensions of thought and practice towards a more complex and critically oriented future.

Table 7: Examples of youth re-seeing practices

Re-seeing Practices	**Example connections to Youth STEM Pathways**
Critically re-defining the world in order to leverage it in new ways	- Keke redefined Wikipedia as a friend of hers, expanding her STEM pathway's social support structure virtually - José redefined power as inseparable from collaboration and trust in teamwork - Amara and Keke's pathway game design sought to invite adults into the complexity of their lives and pathway efforts with STEM
Recognizing more layers or dimensions of life, people, and interactions	- Jazmyn realized that she could build a multilayered, integrated STEAM future that could combine her interests, skills, and commitments - Sincere discovered that his sister could be more than a personal responsibility and symbolic inspiration for his STEM efforts; she could also become a tangible supporter and project assistant pushing his ideas and skills forward

Action for change. Youth act toward goals bigger than learning and development (Calabrese Barton, Tan, & Greenberg, 2017). In this study, they took action with STEM to produce desired changes in the world around them for the benefit of themselves, others, their community, and their pathways. Action for change moved power along pathways and strengthened pathways with that power.

Youth act to restructure their world. In this study, young people's STEM learning and development became more bounded, complex, and real through their actions. Youth took action to change their world when they recognized needed changes and were supported in enacting them. They sought opportunities to take action in the world as a step towards changing unjust reality, and they leveraged STEM as a way to accomplish this action (Birmingham et al., 2017).

For example, Amara and Keke's bus system structural change design was their imaginings of a better reality. It also involved using STEM to prototype that reality for their actual community. Acting with their learning opened up space for Amara and Keke to collaborative explore their city's systems of power and mobility, safety and comfort, injustice and dehumanization, how those systems intersected, and how they could be addressed at a local level. They were also able to explore new engineering knowledge and practices in both more locally meaningful and more wide-reaching ways. As Amara explained engineering's new role in her perspective, "you actually use it to do something." So when they took action to change that system, they also changed their engineering learning and their understandings of themselves within it. Defining STEM engagement through a critical centering of people on their city buses supported Amara and Keke in restructuring STEM learning as a tool for change (e.g., as a step in physical prototype construction for real community use).

Jazmyn also sought a different and more hopeful future of public infrastructure through STEM-rich action out of school, to "make the world a better place." As a sixth-grade student in her afterschool STEM program, she created an iPhone app to respond to community housing insecurity. With her iPhone app, Jazmyn took agentic steps to address the wide-reaching challenge of housing insecurity. She approached the multilayered dimensions of this project by merging her STEM engagement with her lived experience in her community and other community members' perspectives, including community members who had experiences with homelessness or housing insecurity. This interlayered investigation connected questions about contributing risk factors with criteria for app user experience design, and designs for resource-networking with ideas about resource and power redistribution. All of this meant that Jazmyn felt she was doing more than learning app design techniques and concepts: "We were helping out in our community more. Like we were in homeless shelters asking questions to help us improve our app."

This world-restructuring involved moving and sharing power with each other, as a cooperative action to transform realities (Freire, 2007, p 168). As they rejected hierarchical power structures mediating opportunities for STEM pathway development, their power-sharing led to restructured possibilities in STEM for them and for their peers and communities. For example, José pushed for a collectivist philosophy of science learning and practice, explaining, "In science, there is more than one person doing the job. There's always teamwork included in it." He used his Afterschool STEM Program as a space to enact his vision of a more collectivist science practice: "We all listen to each other's ideas and we work together as a team by talking to each other."

In another example, Keke's anti-attack coat was STEM-rich action to take back and share power with other girls: "I want to help those girls, to help them to not do things they don't want to do, and to not … have their bodies exploited if they don't want to," Keke explained. She pushed for using her engineering design skills to address findings on sexual violence against young women, especially young women of Color in her low-income city neighborhood. She wanted to use STEM to address serious and real safety concerns by developing a tech solution to protect and empower girls. Her coat design was an intersectional effort to reclaim and share power through STEM engagement for results that mattered.

In another example, Sincere worked in the Afterschool STEM Program to reimagine structures of ownership over playroom equipment with younger children through his design and construction of a shorter and more young-child-friendly bumper pool table. Inherent in this design was a lower risk of older youth wanting to take the table (because they would be too tall to easily use it), ensuring younger children more sustainable control over their own playtime resources. His design showed younger children care that revolutionized their gameplay options after school.

Youth act to restructure learning ecologies. Youth recognized the architectures of their learning ecologies, and they challenged the constraints of those ecologies as they sought to improve them, redefine them, or replace them with alternative structures of their own design (Shin, Restrepo Nazar, Greenberg, & 16 Youth Makers, 2018). They acted to change the physical and social structures that framed and affected their pathway construction, in order to better support their own efforts to move and act across the spaces of their STEM pathways. For example, they actively sought resources to support pathway movement. This could look unconventional, however, which sometimes meant that the act of seeking a resource was also an act of restructuring what resources were defined as pathway-relevant. Where traditional forms of learning ecology support were inaccessible, they sought non-traditional forms to construct the ecologies that supported their pathway movement.

This could include challenging boundaries for greater porosity to support their critical mobilities. This happened when Sincere argued that interrupting his afterschool STEM engagement with basketball time helped him to clear his mind of stress and refocus his energies on STEM. Keke also demonstrated this by restructuring family doctor visits into field trips. For example, she collected "all of the pamphlets" at doctor's offices as medical science educational texts to be studied. This pivoted and leveraged structures accessible to her in dimensions of patient care and marketing. Her hack allowed her to access medical science learning that she then expanded with online investigations, essentially charting out and completing her own independent studies course assignments as weekday evening activities in her room.

Keke often pulled her sister into these explorations, sharing her hack and the pathway benefits it made available, thus opening up connections between learning spaces. The internet became a resource lifeline that supported their shared efforts to learn in STEM with more porous boundaries between learning spaces and more nontraditional support structures. Keke, especially, turned to it daily to access support that she could not find in real life, joking, "Me and Wikipedia are friends." Where she lacked in-person spaces for discursively sharing and digesting the knowledge she was gathering, she developed a nontraditional social relationship with personified technology. This type of role-played socialization was an access-bridging tool for gaining virtual mentorship and a sounding board of sorts for thinking through her learning out loud.

Youth also replaced traditional components of learning ecologies with alternative structures that could better serve their pathway construction efforts. The internet was a popular space of possibility where youth in this study co-created vibrant learning ecologies in ways that were inaccessible to them in real life. Like Keke and Amara, José and his group also engaged in this practice, but this time to provide alternative digital structures for other youth where they witnessed traditional STEM learning structures failing. José did not find support for any of his more advanced STEM interests (e.g., bionics) within the walls of school. He also explained that in the era of the Trump administration, there was a more urgent need for infusing a social justice focus in STEM learning and practice. His actions drew from his experiences witnessing the 2016 election, the national dialogue on racism and how it had taken on new forms during and after the election, and his experiences living as Biracial Black and Latinx in the United States. They also drew from his concerns about misinformation around socioscientific issues and risks of lost funding for STEM education at a national level. His group used their media familiarity as a STEM resource to reach out to and support other youth like them. Their by-kids, for-kids STEM-education YouTube channel expanded access to STEM learning while providing a platform for more racially diverse representation in STEM and more topic-diverse exploration in STEM in a way that could speak back to injustices of school resource levels and inequitable distribution. This was a design to grab justice back for youth that he argued was taken away by adults in power who were not listening to youth. As he explained, "It's important for us to have the knowledge so we learn more and can be more successful in life."

These efforts critically redefined what STEM ecologies could look like and include. This could also be described as actions of *path-hacking* into STEM, in that they were efforts to create new openings where pathways did not exist or were inaccessible before. These actions youth took allowed for new types of relationships with STEM learning and practice to grow, effectively creating more equitable opportunities for pathway construction with STEM.

Youth act to restructure roles and relationships. New actions youth take with STEM learning and practice leads to new roles and creates new community and pathway relationships for youth (e.g., Calabrese Barton & Tan, 2010). In this study, new roles and connections supported and expanded youth pathway work in transformative ways. Keke and Amara, for example, established new roles for themselves and for others in their community when they became teen STEM mentors together. Taking action in their program led to a new structure for maintaining their access to what they described as their most important space of STEM learning and development. Amara became known as the go-to mentor for help with science writing, and Keke gained fame for her intersectional feminist engineering design. Their volunteer positions turned into a part-time job that they then leveraged for college planning assistance and extended mentoring from university adults through the program. For example, when adult program mentors presented their joint engineering design project at a university research conference, the twins made plans to include the participation certificates they received from the conference in their future college application materials. This, they explained, would communicate the institutional connections they already had as the form of power to help them move into further positions of university power.

Beyond only helping their own STEM pathway development, however, Keke and Amara were actively supporting younger STEM enthusiasts' pursuits of their own dreams as well. They engaged in this effort through their mentorship afterschool, but they also worked towards restructuring relationships between adults and youth through their pathway game design concept. Their goal was to change how adults saw youth in STEM by "learn[ing] from us about how we learn and live." This was an effort to change how power structures mediated pathway movement for them and other youth who experienced the same constraints and frustrations as them. They wanted other people, especially adults in power, to see action differently by entering a more youth-honoring perspective, to ultimately help "kids get better access to STEM."

In another example, Sincere recruited multiple friends as his new support team when he joined our program. Sincere was popular outside of his Afterschool STEM Program, with basketball friends and video game-playing friends. He brought this popularity into the STEM space, leveraging his social standing to create a working group around the engineering design effort he desired, his bumper pool design project. His autonomy was important to him across his life spaces, so when he found opportunities for autonomous engagement in our program, he appreciated it: "I don't really like having to listen to other people's orders when I'm working." But he quickly realized that he could achieve his project goals faster with the support of knowledgeable teammates, so he moved his friends into his STEM space. In this way, he co-opted his STEM learning space and turned it into an extended hangout space afterschool. But he also co-opted his social power and transformed it into a STEM support structure through this process. Beyond leveraging his friendships to support his productivity, he also shared his STEM resources with these friends by supporting their entry into that learning space.

Jazmyn likewise leveraged her family's social connections to tap into expanded social structures that supported her efforts to explore STEM futures across multiple life spaces over time, as evidenced by her mother's assistance in traveling to star in a local TV station's science learning program and follow-up emails with the station about her daughter continuing on the program for a second season.

Youth constructed STEM pathways within structures that mediated their actions. Changing those structures was transformational for their efforts. They actively work to restructure spaces, events, relationships, and future possibilities towards more equitable possibilities for them and for others.

Table 8: How youth took action to change STEM pathway structures

Types of Action	How Youth Action Changed STEM Pathways
Changing the world	- Jazmyn worked to change her city's resource structures for people who needed housing support, through STEM-rich design in her phone app project
Changing their pathway spaces	- Keke, Amara, and José used the internet in different ways to expand access to STEM learning spaces through creative, alternative STEM resource connection - (José's project was also an effort to change the world's STEM engagement access as well as his own)
Changing STEM pathway relationships	- Sincere expanded his pathway support after school by recruiting friends into his STEM work - Keke, Amara, and José all sought out roles as Afterschool STEM Program mentors to benefit from the role's connections and capital in STEM

Processes of Becoming

Youth efforts to navigate their world as it is and recreate the world as it could be provided powerful spaces for them to imagine themselves differently in STEM. This re-imagining reflects the third and final layer of phenomena that make up youth pathways, which I term *becoming*. The pathway dimension of becoming could be described as an ever-under-construction process of youth pathway movements to their futures. Youth in this study navigated pathway structures of resources, space, and time to get where they wanted to go in life. At the same time, they leveraged feelings of purpose to engage more deeply in learning and development, and they worked to re-see their world with greater possibility as they took up actions to change that world for the better. These efforts led them into a new experiencing of reality and a new dimension of being with STEM. It also helped them expand possibilities for themselves to be and become by expanding their world's present and future possibilities (Calabrese Barton et al., 2013).

As ever being re/constructed by youth, becoming can be defined as an ongoing process towards a future self, a self that is somewhat-still-fluid but always gaining firmer shape. People are not static beings but are always in a process of becoming (even if changes appear so subtle as to be ignored, those changes continue over time). They continue to learn and develop throughout life. As youth continue to *become* along their pathways to their futures, they gain power over their lives and futures (e.g., Calabrese Barton et al., 2013). This also extends the *power* dimension of pathways in that both wielding power and sharing power with others provides youth with greater power to become, moving forward.

For the youth in this study, constructing a STEM pathway involved moving in the present while imagining and creating the future. It was about being humans with STEM learning and practice in new ways, but it was not a pathway endpoint. This aligns with Michelle Obama's (2018) argument about becoming as a continual identity-work journey that echoes the continual evolution of the world around us, always seeking further movement or "reach":

> For me, becoming isn't about arriving somewhere or achieving a certain aim. I see it instead as forward motion, a means of evolving, a way to reach continuously towards a better self. The journey doesn't end… I have become, by certain measures, a person of power, and yet there are moments still when I feel insecure or unheard. It's all a process, steps along a path. Becoming requires equal parts patience and rigor. Becoming is never giving up on the idea that there's more growing to be done. (Obama, 2018, p 419).

It was an ongoing and contentious process of producing "motion" forward across space and time.

A process of tension. This study's findings revealed that the process of becoming develops within that tension of surviving in the world as it is while imagining and working towards the world as it could be. Moving within this tension, all youth in this study became more aware of possibilities for their pathways moving forward. These possibilities included but were not limited to a) moving into new realities as they envisioned and created them, and b) moving into new ways of being.

Envisioning and creating new realities in the world helped youth expand their notions of what they could do and experience. By realities, I mean the development of new relationships with pathway components and power structures as youth continue to move toward desired futures (e.g., new learning connections and new enactments of practice across space, new material relationships with technology, new interactional relationships with adult STEM professionals, etc.). This idea builds upon prior literature on youth movement towards possible futures (Calabrese Barton et al., 2013) but with a focus on expanding and shifting the material and interactional present that structures movement towards those futures.

For example, José envisioned a future working towards justice in cyber security by becoming more capable of protecting himself and his community. He understood this process as possible, because he could recognize that he was gaining specific STEM skills that could help him fight back against "people who wronged me in life," including strangers online who had stolen from his friends: "I'm gonna probably be one of those CSI or FBI agents that can track down these hacker people for doing illegal stuff, any kind of hacking, for bad use. I will be the world's greatest hacker-tracker." He explained that his STEM engagement out of school, including his leadership work as an online activist and STEM community mentor, was forwarding his pathway towards technical activism in additional possible directions, all servicing his efforts to become "a computer genius."

Jazmyn, too, saw her possibilities to become as expanding over time as she reached new ways of exploring and affecting the world around her. For example, she tried out new possible futures with each new interest she explored and with each new space she entered. The people around her leveraged their collective wisdom to support this effort of exploring possible futures, an additional layer propelling her forward along a pathway of increasing complexity and connectedness. Through her successes across multiple learning areas and her out-of-school engagement across a diversity of professional disciplines, she developed a vision of the world as a place where she could continue to explore her various passions in the future. Her envisioned career, therefore, involved a multifaceted leadership role in STEAM (science, technology, engineering, art, and math) including responsibilities of engineering-informed community organizer and developer, chemistry-informed chef, and high-technology fashion designer. All of this, she explained, would occur in a community-welcoming space that likewise provided other people in her life with a spectrum of engagement options.

As youth moved into such new realities along their processes of becoming, they also moved into new ways of being. By ways of being, I mean positioned roles and repertoires of practice that constitute active living in relation with communities across space and time (e.g., Calabrese et al., 2013, p 41). Constructing a STEM pathway was not a journey alone or out of social contexts, and youth engaged with others as they continued developing themselves. José's STEM pathway, for example, involved becoming a person with the skills to be "way better at making [science] and discovering more about it" within a supportive team of other scientists. His identity work could not occur in a social vacuum. His pathway would only develop in partnership with others. "In science, there is more than one person doing the job. There is always teamwork," he asserted. In his portfolio drawing of what science could be in his envisioned future, he depicted a plasma ball of energy with multiple hands on it. This revealed his vision of a new reality of human interaction, in which powers of multiple people combined happily and with purposeful, collective force to act through teamwork.

Sincere's new reality that he was seeking through his STEM pathway, conversely, involved detaching himself from constraints of human interactions and the power hierarchies they enacted. If he could construct a new social structure for his future that did not require him to listen to others, he would be able to explore a future reality for himself in which he could listen to himself instead. Still, he maintained the hope that his own developmental efforts would widen pathways of opportunity for other youth in the future, including but not limited to his little sister. This hope echoes Obama's (2018) discussion of her desire that her own efforts to be and become as a person in the world might produce a positive ripple and "widen the pathway" for others to become who they want to be (p 421).

In another example, while school did not provide opportunities for Amara to act and "do something" with her learning, her afterschool program gave her "a lot of things I do" that allowed her to create an identity-in-practice as a "science and engineering major." Because she knew herself in the present ("I'm not the type of person who learns by watching"), she knew such alternative opportunities, beyond institutional norms, would be required to support her in constructing the medical sciences person she desired to become.

Keke, conversely, desired to become a different version of herself (e.g., more recognizable as a "nerd") who could gain recognition *within* traditional structures of STEM learning and practice. But she also wanted people to recognize her as being "weirder than most" and "very different," qualities she believed should be valued as important resources in the contexts of STEM learning and practice. This tension played out in a pathway that involved expanding out from the constraints of the traditional power structures that mediated her present possibilities to be and become, through engagement out of school that sought to change her world in imaginative ways. As she critically engaged in the world around her, problematizing and acting to change it, she began to re-see herself as someone in a process of becoming important in and with STEM. For example, it was during a voluntary engineering project to change her city’s infrastructure in social justice-informed ways that she felt an identity-in-practice as a “science person.”

The process of becoming enhanced possibilities for youth. Each of the youth in this study began the study in a different place and imagined a future that was unique to who they were and wanted to become. As they sought to author pathways towards these imagined futures, their efforts to become interacted in tension with the world as it was. Following diverse purposes that guided and centered them, youth worked to recreate the world as it could be through new sight and new action, to open up new possibilities for becoming that did not exist in the world as it was. When youth accomplished this change for their own pathways and the pathways of other youth in their communities, they developed new perspectives of themselves, the world around them, and their possibilities for their futures.

Table 9: Cross-cutting themes, theme dimensions, and sub-categories.

Theme	Dimension	Sub-categories	
		Forms	Navigational practices
Navigating the world as it is	Resources	STEM resource diversity	Leveraging untraditional physical STEM resources Leveraging untraditional social and symbolic resources
	Space	Cultures and opportunities of STEM spaces Physical STEM spaces	Keeping Silent Imagining better future spaces Lobbying adults for assistance
	Time	Time as pathway constraint Time as pathway support structure	Redefining time Reimagining time Building power with time
		Practices to Transform	
Working towards the world as it could be	Purpose	Planning out pathway navigations Drawing strength from family and community Purpose connected to time	
	Re-seeing	Critical Redefining Recognizing dimensionality	
	Action for change	Youth act to restructure their world Youth act to restructure learning ecologies Youth act to restructure roles and relationships	
Processes of becoming	Becoming in dynamic interaction with the world and with others, as an ongoing, forward-looking process		

Chapter 6: Pathway Research Reimagined

My dissertation investigated how youth who engage in informal STEM programs construct pathways across their varied spaces of learning and development towards desired futures in STEM. This included asking what their pathway-making efforts look like and include over space and time, how those efforts are structured and/or supported, and how youth, in their own words, understand those efforts.

To answer these questions, I developed new methods and approaches to collaborate with youth as research partners so that I could learn more directly from them, in their words and from their perspectives. I explored STEM learning and development pathways with youth who I knew were seeking STEM-related futures. Partners included five Youth of Color from a low-income community in Michigan whom I had known and worked with for years in an informal STEM program. With critical ethnographic participatory research and critical participatory co-analysis, we explored their efforts to construct STEM pathways across life and analyzed research findings about those efforts in more collaborative ways than what prior research tools had made available.

My study found that youth constructed STEM pathways through practices of a) navigating the world as it is, b) working towards the world as it could be, and c) processes of becoming. These practices demonstrated how youth in this study experienced and made sense of their pathway construction efforts within and against the worlds in which they live as they moved towards their futures.

Below, I discuss how these findings advance the literature on a) understandings of learning ecologies and pathways, b) why methodology matters in how researchers learn about pathways, and c) lessons around equity in informal science learning. This discussion concludes with d) important implications for practitioners working in out-of-school learning environments, especially White adults working with racially and economically diverse populations of youth.

Discussion

Advancing understandings of learning ecologies and pathways. This dissertation presents the field of educational research with a new understanding of learning and development pathways across life. Findings push the literature forward by rethinking what pathways include for the youth who construct them, how youth navigate the world towards their desired futures, and how they reconstruct their world in order to reach that future.

Rethinking pathways. Pathways ground learning and practice in historical, physical, and contextual geographies or ecologies that overlap and intersect across space and time to form a complex terrain of life. Youth construct pathways across this terrain to create themselves as they create their desired futures. This study sought to explore how youth accomplished this work, with a deep dive into longitudinal data with a critical participatory lens. This effort resulted in a new and more complex conceptualization of what pathways include, how they are constructed, and what this means for both youth and adults who seek to support their learning and development efforts in life.

Pathways of learning and development are ways in which young people come to understand, navigate and leverage, and reimagine and reconstruct dimensions and interactions of their lives as they seek desired futures for those lives. Complex dimensions of life structure the terrain on which youth describe their pathways, in that they provide the material and experiential components that youth interact with.

Pathway construction includes young people's attempts to inscribe agentic movement across power-mediated life terrains through understanding, navigating, and leveraging dimensions of resources, space, and time. Youth ground this effort in specific pathway-related purposes that connect the self and learning to family, community, and world. They also plan out strategies for surviving and navigating across dominant and externally determined power structures that bound and mediate formal learning spaces, leveraging structural tensions as reasons for more urgent action.

Pathway construction also includes young people's attempts to reimagine and reconstruct life terrains towards the creation of a world with expanded possibility for the future. This is where this dissertation pushes theoretical limits further, by recognizing and exploring youth imagination and youth action to turn imagination into reality through radical structural change (see example theoretical figures below).

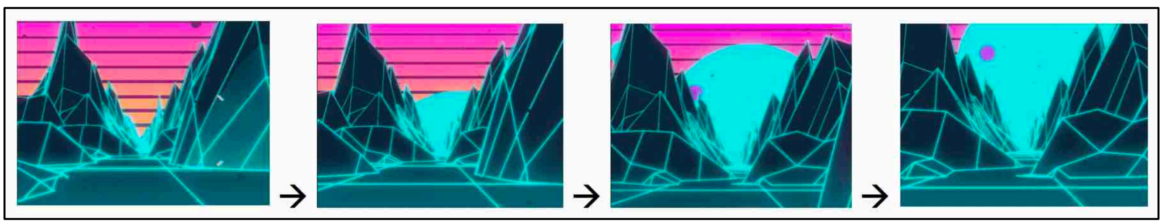


Figure 23: An abstract representation of pathway construction as becoming through navigating the world towards expanded possibilities (the expanding shape on the horizon symbolizing expanded possibilities to enter and explore through future practice)

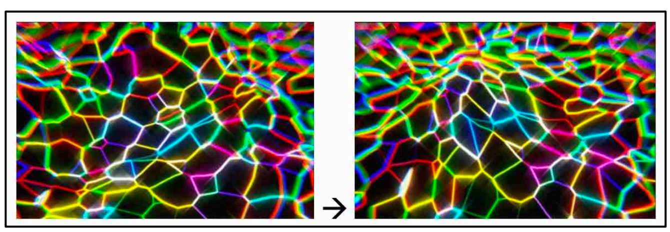


Figure 24: Pathway construction as becoming through restructuring the world towards expanded possibilities. This abstract conceptual figure is meant to represent shapes of STEM connections changed within the same space for the same individual from time A to time B, a symbolic representation of differently formed opportunities for exploring new ways of being and becoming in STEM.

Building on current understandings. The current field of research on learning ecologies and pathways discusses movement through ecologies in the world (e.g., Bright et al. 2013; Bell, Bricker, Reeve, Zimmerman, & Tzou, 2013; Leander, Phillips, & Taylor, 2010; Barron, 2006). For example, cultural learning pathways discusses learning and development as youth navigations across life spaces in relation to cultural value systems (Bell, Tzou, Bricker, & Baines, 2012). Racialized learning pathways also discusses learning as youth efforts to move through organizations of culture in existent domains (Nasir & Vakil, 2017).

My study builds on this helpful knowledge base by showing this movement too, in part, but also reaches beyond to reconsider navigational components, towards expanding understandings of *how* youth navigate pathways in the world as it is. This involves questioning what counts as pathway resources and how (e.g., who can define a resource as a STEM resource) and questioning how youth understand and agentically leverage space and time as pathway dimensions in ways not previously covered in research.

Resources. Youth in this study navigated and leveraged untraditional physical, social, and symbolic STEM resources in ways that spoke back to tradition and power structures creating those traditions. This involved such practices as re-designing shared resources in order to share power with others (e.g., in Sincere's design of a bumper pool table for younger children) and developing hacks to connect to traditional resources through a co-opting of untraditional resources (e.g., as Keke co-opted doctor office pamphlets as starting points for independent medical research projects) It also involved leveraging social and institutional power in creative ways (e.g., in Sincere's friendship leveraging for gaining work assistants, in Jazmyn's use of her mom's social media account to start a painting business, etc.).

Space. Youth navigated physical constructions of STEM spaces that grounded and constrained their learning and practice. They also navigated power-mediated norms of STEM spaces. Navigating norms required developing and leveraging explicit understandings of what norms existed and how cultural norms mediated their practices and talk in different ways (Ispa-Landa & Conwell, 2015; Leath, Mathews, Harrison, & Chavous, 2019). This involved drawing boundaries around different spaces of their lives where they engaged in STEM pathway work and categorizing bounded spaces based on what norms were created within the spaces' differing power structures. Youth leveraged their understandings of spaces to direct specific navigational practices including keeping silent as a strategy to conform and avoid tension escalation within structures of power that did not support them (e.g., as Amara explained in her narrative), imagining better future spaces as a strategy of critical hope and emotional self-support (e.g., in José daydreams), and lobbying adults for assistance through developing relationships of trust with specific power-holders (e.g., Jazmyn and Sincere focused heavily on this strategy).

Time. Youth developed understandings of time as a pathway structure of both constraint and support depending on context. These understandings helped them to create their navigational strategies in response. They also leveraged time as a contextual and flexible STEM pathway-making tool, in ways that complicate and expand traditional understandings of time in youth learning and development. These leveraging practices included reimagining time (e.g., in José's mental time travel work during his daydreams) and building power with time (e.g., when Keke argued for recognition based on temporal evidence of committed participation in STEM out of school).

Considering how youth seek to create the world as it could be. Through their pathway work, youth opened up new possibilities for themselves by critically imagining new possibilities for the world around them. Current literature examines pathways as a framework for how one navigates the world as it is (e.g., Gallard Martínez et al., 2019; Maltese & Cooper, 2017; Nasir & Vakil, 2017; Bricker & Bell, 2014; Bell, Tzou, Bricker, & Baines, 2012). Beyond expanding understandings of *how* youth navigate pathways in the world as it is, my study reveals that youth do so with an orientation towards constructing a world as it could be. Such work occurs in how they imagine their future selves and future action possibilities, but also in how such imaginations offer purpose and direction to how they seek to redefine their worlds, their places in it, and the actions they take to make that possible.

Findings uncovered ways in which youth-directed pathway efforts play out across learning ecologies as youth expand notions of what counts as movement across ecologies; what power dynamics can look like in pathway development; and how youth can leverage complex multidimensionality to critically engage, challenge, circumvent, or replace pathway components and structures towards new presents and expanded futures. For example, prior research had acknowledged home and community resource leveraging as important for youth pathways (e.g., Hand, Penuel, & Gutierrez, 2012; Gonsalves, Rahm, & Carvalho, 2013; Bricker & Bell, 2014). But youth in this study revealed new ways of mobilizing home- and community-grounded resources towards expanded pathway applications that crossed spaces and scales, leading to outcomes that transformed multiple dimensions of learning and practice for them as well as others. This happened when Keke and Amara leveraged their lived experiences and family stories connected to their city's public transportation system as a foundation for their critical justice-informed engineering design project. They had sought to apply this knowledge to develop a solution for their city while building STEM knowledge and practices. Their outcomes of these efforts expanded as they gained recognition for their research by several universities, and for their design suggestions by their mother's boss in the city. Their outcomes also connected back internally for Keke and Amara in ways that differed for each twin, even within the same type of work and the same family contexts. For Amara, the internal shift was realizing new ways she could expand her learning ecologies across life contexts for more purpose-driven STEM learning. For Keke, the internal shift was identity work in publicly legitimized and personally documented ways (e.g., "I'm a science person now") that she and other important people in her life (e.g., her twin) did not previously believe to be possible. Their resource mobilization across power structures that mediated physical mobility in their city challenged traditional notions about resources, mobility, and power in space (e.g., they used their own physical mobilities as a shared lens for strategizing how they could support the mobilities of others across their city, co-opting STEM learning to address political injustices through resourcing public empowerment in embodied forms on the bus/at bus stops). The twins also gained mutual personal and community development along their parallel STEM pathways without the help of formal learning structures, while using their efforts as springboards for further future advancement in formal structures (e.g., presenting at university conferences, preparing college application materials, etc.). Rich data like this, co-generated and co-analysed with youth in partnership, challenges previous notions about what is really required for researchers to accurately see, study, and understand pathways.

Youth worked towards constructing the world as it could be, acting with a critical re-imagination of possibility in learning and development. New understandings of pathway resources, space, time, youth perceptions, active practices, reasons behind youth practices, and power that were reached in this study challenge researchers of pathways and learning ecologies to consider more expanded and more critically complicated operationalizations of such constructs as a necessary step forward for the field. Mobilities of criticality offered us some new tools for expanding and complicating these constructs by pulling out power-mediated structures of interaction so that adult and youth research partners could see and discuss power issues across learning ecologies more explicitly as we explored their pathways towards desired futures. A critical participatory methodological approach also helped us in this effort, as I detail in the following section.

Why methodology matters in how researchers learn about pathways. Exploring youth pathways of learning and development presented youth partners and me with an opportunity to develop new approaches and tools to more thoroughly and accurately see and understand youth efforts across space and time. The level of local depth and connected complexity that we reached in our shared work led to higher-validity findings about youth pathways and the structures that frame and support them, using Lather's (1993) definitions of paralogical and voluptuous/situated "transgressive validity" forms (p 676). For example, critical ethnographic participatory methods of data co-generation with youth allowed us to embrace and foreground complexity, tensions, and problems of representation as central to our research effort, ensuring paralogical validity of findings (Lather, 1993, p 685). Our partnership work also challenged traditional structures of authority in research with self-reflexive positioning and multiplicity of voices throughout the research process, ensuring voluptuous validity (Lather, 1993, pp. 681, 686). The depth and complexity of these findings was made possible only through reimagining what research could look like and include, in trusted and open partnership with youth and within long-term relationships of mutuality.

Approach. First, reimagining approaches for determining research designs used was a transformational act in this work. Building upon critical and participatory traditions of research, I sought more thorough and open approaches to exploring youth lives that could better center those youth as the recognized experts of their own life experiences. I wanted to learn more directly from them, in their words and from their perspectives. This was especially important from my positionings as a White, adult researcher-teacher who was not a member of their immediate family, had not known them across their entire lives, and had not shared in some of the structural barriers they had experienced. Even in our physically shared spaces of learning and practice, I recognized that they were experiencing those spaces completely differently and were engaged with intersecting and layering social and virtual spaces atop the physical ones in ways I could not see or access without their explicit guidance (e.g., friendships, emotional experiences, personal trajectories connecting across time, tensions in navigating power structures to which I had previously been blinded, etc.). The current field of research was limited in prescribing what was really required for me to accurately see, study, and understand wide complexities of pathways.

Critical ethnographic participatory research is a methodological approach combining critical ethnography and participatory research to centralize youth perspectives while challenging inequities they face. It is an embrace of complexity and partnership for more thorough and multilayered data collection through participatory co-generation. It draws from diverse and multi-generational perspectives to examine and address systems of power for more transparent and equitable research with youth. The *deep partnership* that framed this approach necessitated a commitment to co-determine the design for documenting, analyzing, and interpreting youth pathway efforts with STEM. That partnership called us to re-envision what our shared research experience could feel like for both youth and adult as well as what such research could produce. This included new forms of data collection and analysis that could honor and leverage our differing expertise more thoroughly and more transparently across the study, leading to more multilayered findings and representational forms. For example, I was able to layer Sincere's data about his little sister's efforts to structure his STEM pathway with my participant observations of her actions, which Sincere then read through and elaborated on with further commentary about her impact on his pathway. I then characterized this data in a claim of my own wording, which he then tweaked further before inviting his sister to read (at which point he got the idea to stage a candid photograph of his sister reading it over his shoulder, a photograph now included in his narrative).

I found the critical ethnographic participatory research approach to be an important tool in uncovering and attending to power asymmetries and related blind spots in our deep partnership that, if unattended, would have corrupted and limited the rigor of our research process (e.g., through the use of interview protocols that has not undergone a critical youth lensing for critiques and rewrites). It helped me to attend to my limits of sight as a White adult researcher writing about the lives of Youth of Color who were actually living them, in that I was not the only writer of their stories. I could better uncover my own spaces of ignorance, for example, through transparently asking youth for additional layers of their argument to help me see what they meant in a deeper way. I could also better address power tensions inherent in this work by more thoroughly acknowledging my responsibilities throughout each step of the research. This echoes Gutiérrez et al.'s (2017) claim that, "Participatory approaches to education research highlight the intensely relational nature of conducting research with and alongside historically marginalized communities, relations that are always mediated by dynamics of race and power" (p 35). Using a methodology that recognized this relationality allowed me to see dynamic youth leveraging of pathway components I would not have noticed otherwise. For example, if I had not known Jazmyn and her family for so many years, her mom might not have texted me to brag about her daughter's dance performance. And if I had not been conducting research with the flexibility to continually adapt methods and data, I would not have had the opportunity to hear and layer into Jazmyn's narrative her argument about how her dance song's lyrics formed an appropriate representation of her pathway construction efforts.

As a part of our deep partnership and our critical ethnographic participatory approach to this dissertation, my participation in the youth lives we were studying became a subject to explore together with more transparency than might otherwise have been available to us. The research approach helped us to remain open to looking at where our relationships and the overlaps between our learning program and our research project influenced shifts in their pathway construction efforts and/or shifts in how we studied those efforts. I was able to directly ask youth, for example, what my role was, if any, in particular events they had discussed as key to their pathway efforts. This allowed me to see where I was merely observing change versus eliciting change in their pathways (e.g., through my teacher/mentor actions in their Afterschool STEM Program, in their museum Youth Action Council, in my brokering efforts with parents and community leaders, etc.).

We had taken a participatory design-based research approach to the development of the makerspace in which the Afterschool STEM Program was held and the activities and goals we engaged in that program (e.g., Shin, Calabrese Barton, & Johnson, 2016). This necessitated, then, an attendance to how much of what we were studying was reflective of generalizable structures of power and practice that might be seen elsewhere (e.g., in other afterschool STEM programs) and how much was reflective of structures we had deliberately co-designed together to support successful youth pathway construction. Drawing from the critical ethnographic tradition of research helped us to zoom in on these reflections in specific ways. For example, in interviews, I was able to ask youth to consider what components of different events in their afterschool program made them supportive for their pathways (e.g., including which mentor and/or peer interactions, and how), but also what could have gone better or felt more supportive (e.g., including which mentor and/or peer interactions, and how). A context of deep partnership aided in mutual transparency within a relationship of nonjudgment and trust during such interviews. This allowed youth a space to state, for example, what components were missing from my mentorship that they hoped to find from a STEM expert when they entered college, or why a particular moment we had shared together was influential for their development of a sense of belonging and recognition in STEM.

Importantly, our longitudinal critical ethnographic data already collected and our long-term relationships outside of the study added crucial layers to our data co-generation and co-analysis processes, layers that increased our quality and scope of findings. Future research using this approach would not look the same or reach the same complexity of findings without such a context of time, trust, and friendship with youth and their families.

Data. Second, critical participatory co-generation of data through the co-construction of portfolios of youth pathway forms, components, and tensions shifted and expanded possibilities for our findings. These portfolios drew from understandings of embedded case studies but developed those cases through a critical participatory co-construction process. Youth critiques of my interview protocol drafts, for example, enhanced my ability to enter the field with confidence in the precision of my researcher tools because the "researched" was also the "researcher" with me. In this way, we also drew from the critical ethnographic tradition of recognizing the researcher as research tool, but we used a participatory approach for honing that tool.

Furthermore, rather than have youth construct portfolios and then exit the data collection process, youth research partners maintained a level of control over their data throughout the next steps of the study procedure. This enhanced my ability to reach more complex findings by allowing me access to youth expertise on their data throughout all stages of the research. Even as the study progressed into analytical work, youth had access to their portfolios and changed their data when they felt it was necessary (e.g., through them or their parent texting me a life update or a photo to add to their portfolio, through them deleting, suggesting, or directly entering new text, etc.). This new type of effort helped us to better understand the complex components, structures, and interactions of youth pathway construction efforts.

Analysis. Third, *critical participatory co-analysis* of our co-generated data produced more complex and critically informed findings that could better assist us in advancing research on youth learning and development pathways, STEM education, and critical participatory methodologies and methods. It enhanced our growth together as partners and the research we produced through that partnership.

For one thing, both youth and I shared at different points that reimagining methods of analysis made us feel powerful by expanding our possibilities for reaching findings together and strengthening our mutual trust in one another and in the process. I observed this in iterative layers that could be explored further in future methodological inquiry. For example, hearing youth partners explain their experience of increased ownership over their stories and materials, and their trust in me as a partner, increased my trust in myself as a research tool and my trust in our analytical partnership work as a beneficial decision (even when co-analysis demanded more patience, open-mindedness, and time investment than I originally factored).

Furthermore, findings that resulted from critical participatory co-analysis were more richly layered and more attentive to critical tensions inherent in the dynamic nature of pathway construction over time. There were multiple instances, for example, in which our reimagining of traditional practices of participant member-checking led us to completely different directions in our findings than would have been possible otherwise (e.g., through me asking them not just to confirm a quote, but to confirm its relevancy to a particular turn in their narrative, and to wonder with me on its possible connection to one of our co-developed claims).

This analytical advancement of the participatory research tradition raises important questions about what is possible in research with youth and what components of taken-for-granted research repertoires are ripe and waiting for more attention and redesign. But this analytic method required specific conditions for enactment, including sustained follow-through of analytical commitments on my end and sustained buy-in from youth partners at multiple levels during the months in which analysis was conducted, written up, and edited for this manuscript. For example, I instituted a rule for myself that if I introduced an analytical claim that had not been spoken in some form by youth partners, I had better be ready to present my argument with multiple forms of evidence to those youth partners when we next met. And if I changed a claim's form (e.g., from "that helped me later" to "that supported her mobilization of learning through time"), same rules. Positioning youth partners as akin to internal review board members with final approval over all research actions helped me to assume primary responsibility for research-production labor while checking my own desire to make non-participatory decisions about how to direct that labor.

In this way, I sought to strike a balance between owning my dissertation knowledge production but not seeking sole ownership over the intellectual property of our knowledge co-creation about youth pathways. In attempting a new participatory approach to knowledge construction, I had to critically question my own actions in each step of the analytic process, "as a contested and partial process in tension with the institutional and cultural durability of the more linear knowledge transfer paradigm" (Anderson & McLachlan, 2016, p 295). For example, I derived my use of the term "mobility" from youth statements about movement of self and resources for learning but also from theoretical traditions and concepts I had read about as a graduate student. This resulted in a hybrid but still partial definition of youth mobilization along pathways—partial, because it still required a follow-up check with youth partners to present to them (and open up to critique or rejection) the way in which I was hoping to use the term in this dissertation (youth approved my use of "mobilize" in writing but changed it to "connect and move" in research conversations, interviews, etc.).

I recognize that this new analytic method requires further attention regarding potential research applications beyond the purposes of this dissertation. It also necessitates a follow-up discussion with the field about constraints and requirements of faithful enactment (e.g., requirements about transparent sharing of relevant research concepts/terms and theory with youth research partners, and example cases of how/why one would make educational theory accessible to youth). For this reason, one important future research direction will be a deep dive into criteria of quality in researcher enactments of critical participatory co-analysis, to ensure rigor and validity of application and clarity of terminology.

Researchers have called for more frameworks and tools to explore challenges in STEM education (Feinstein, 2017; Philip & Azevedo, 2017). I offer *critical participatory co-analysis* as a transformative tool that led our research collaborative to new knowledge built from multiple data points and perspectives that had not been accessed by researchers before. This new type of knowledge is grounded in the acknowledgment of the legitimacy of youth expertise over their own lived experiences and pathway contexts. I ask that future researchers of youth pathways and ecologies take up such an acknowledgment, either through *critical participatory co-analysis* or using additional tools, as a joyful commitment to richer truths and more thorough power-sharing in participatory research on youth lives.

Lessons around equity in informal STEM learning. This study used a critical justice definition of equity to examine the complexity of youth pathway efforts, taking into account diverse and intersecting positionings in systems of power that mediated their access to resources and influenced their purposes, perceptions, and actions. This stance matters because it situates youth pathway construction in much more complex terrain than existent literature suggests. Ecologies are not just dimensions across with youth navigate; they are layered in complex and dynamic ways with power so that the structures which sustain systemic injustices insidiously locate themselves within daily routines of practices across life. This includes routines and designs of out-of-school STEM learning spaces that purport to enhance equity for youth (Dawson, 2014). These findings increase the urgency for educational researchers and policymakers to better understand youth perspectives and practices of their learning mobilities and geographies, with a special focus on how to support more equitable and transformative opportunities to be and become with STEM out of school.

Along with other researchers, I recognize value in centering youth as thought leaders and action-takers (Greenberg & Calabrese Barton, 2017; Birmingham et al., 2017; Vakil, 2014), drawing from community ways of knowing (Barajas-López & Bang, 2018; Barton & Tan, 2018), and working towards social justice in concrete ways with STEM (Taylor & Hall, 2013; Calabrese Barton, Tan, & Greenberg, 2017). Youth partners and I call for research to build on these traditions in ways that seek to continually unpack the increasing complexity of equity issues across space and time as youth seek their desired futures. For example, José's interest in bionics and hacking connected in complex ways to multiple layers of inequity and injustice, related but not limited to his family history, his personal friendships and still-developing ideas about performed masculinity, his lived experiences of racialized violence and injustice across multiple scales, his ever-developing ideas around protection and empowerment, his desires for public recognition, his STEM identity work amidst tensions in his math coursework, his particular understandings of power and how it is developed in interaction with social others, and his visions of justice for youth in the world.

Youth of Color and youth from low-income communities are active in their learning and development across space and time, as are their families and communities. The youth in this study are leaders who call for changes for themselves and for "youth like us." They seek justice in and across their learning spaces, and they seek recognition from adults who have the power to support them in achieving such justice for their pathways. As youth moved purposely towards their desired futures with STEM, our study explored how this was made possible against structures of injustice that sought to slow them down or turn them away. Future research on equitable structures for youth engagement in informal STEM education can build on this study's findings by embracing more uses of multidimensionality in framing questions and pursuing answers. Looking at phenomena such as how youth mobilities play out across informal STEM learning spaces requires empirical recognition of dimensions of life as multiple, overlapping and complexly interwoven, and continually in shift as they interact across structures of power.

Each individual young person needs and desires something different across overlapping and intersecting dimensions of their historically and socioculturally informed presents and futures, echoing critical justice approaches to understanding and building towards equity in informal (out-of-school) STEM learning. Youth in this study demonstrated that designing better support structures *for* youth demands that adults design those structures in more honest *partnership with* youth, the experts of their own life contexts and spaces. Youth also demonstrated that adults who research youth engagement in informal STEM must explore youth efforts with a greater level of complexity that acknowledges the multidimensional and intersecting realities of equity and justice.

Connections to K-12 education. This dissertation argues for re-approaching structures of education through a lens of youth-adult partnership. While the dissertation focuses more thoroughly on out-of-school data, implications for adult practitioners are not bounded to out-of-school spaces. Learning and development pathways traverse and comprise formal as well as informal spaces that youth move within and across; in many cases, formal spaces and the structures of practice within them featured most prominently in youth accounts of what stood in the way of their pathway construction efforts (e.g., the limited repertoires of practice available to José in his math class, the assumptions about identity and capability that teachers enacted differently in Sincere and Amara's STEM pathway narratives, etc.).

In and across school settings, adults can affect youth pathways in positive or negative ways. Because youth learning ecologies are complex and overlapping, adult K-12 teachers and administrators are uniquely positioned to shift and accelerate youth pathways. As argued earlier, ecologies are not just dimensions across which youth navigate; they are layered in complex and dynamic ways with power so that the structures which sustain systemic injustices insidiously locate themselves within daily routines of practices across life. This means that while teachers and students are positioned differently in matrices of oppression and privilege, power inequities are not always readily visible (although they are always consequential for youth pathway efforts, increasing the urgency of teacher efforts to uncover them).

Efforts to leverage one's institutional power as a teacher or administrator to ensure a position as "pathway supporter" (as opposed to pathway obstacle) can begin by learning about the pathways across life that youth desire to construct. Beginning each school year with a group discussion about possible future goals and dreams, for example, can open up spaces of dialogue for youth to share their school learning-related desires and needs for support in ways that they may not have felt invited to do otherwise. Such explicit invitations for youth to share their dreams (both their longer-term dreams for life, and their dreams for what they might do in our learning space) aided me in reaching across youth-adult social divides as I got to know each youth partner of this dissertation. Furthermore, it helped me as an educator and curriculum designer to know where youth needed different types of support than I had assumed, support that required specific follow-up actions and decisions (e.g., one such conversation led me to hold meetings with technology administrators to get past institutional firewalls preventing youth from using YouTube.com as a tool for STEM educational design).

Teachers who wish to take up the work of supporting youth pathways in classroom practice could also begin by exploring connections youth already seek to draw between in- and out-of-school learning. Learning about how youth engage in pathway construction efforts outside of school could assist teachers in recognizing where potential new connections could develop as well as where current connections could be better supported and leveraged. For example, Keke's interest in using doctor office pamphlets as medical science research materials could inspire teachers to institute a whole-class challenge to bring in everyday informational materials as research tools informing broader and/or deeper, youth-directed investigations into everyday scientific phenomena (e.g., a shampoo bottle's chemical ingredients list, a cereal box's nutritional facts panel, a a household cleaner's safety warning, etc.).

Teachers interested in adjusting their own social practices in school settings towards enhanced relationships with youth could also use the framework of pathways to situate themselves in broader life context as part of young people's critical mobility support teams. Teachers could, for example, learn about what/where/how youth seek to mobilize learning resources across space and time, through questions including but not limited to, "If you had unlimited time and resources, how would you want to explore this topic more at home this coming weekend?" and then, "If we made that plan more feasible and broke it down into multiple steps, what goals should we set together for Step One?" This could be leveraged as an opportunity to re-position oneself as a learner and re-position students as teachers. Given the situation set up with the above example questions, this could also be an opportunity for the type of youth-adult co-design and co-ownership over learning that youth reported as consequential for their pathway efforts.

Further implications listed in the following section can be considered relevant across both formal and informal learning environments. These include, for example, enacting anti-racist pedagogical commitments through daily practices of self-reflection and critical self-adjustment (e.g., with the help of a daily journal and/or weekly meetings with trusted, critically minded colleagues), and transparent communication with youth and parents to support the development of more partnership-type practices in the classroom.

Implications for supporting youth pathways in practice. Youth research partners sought to not only advance understandings of youth pathway efforts for the research field, but to support practitioners of youth STEM education across spaces by providing them with some tools to help support those efforts. They desired to affect change through public education on their STEM pathways, including teaching those who affected their pathways in local ways within and across their learning spaces.

Speaking back to powerful adults who structure youth pathway efforts was a valued goal of this research effort. Our work involved zooming in on how adults with power over youth STEM pathways (e.g., parents, teachers, program directors, and policymakers among others) affect youth efforts to construct pathways for themselves. It also sought to document and discuss some critical ways in which youth are challenging such power-holders, many of which were previously overlooked in research. Youth are active, for example, in designing new, youth-owned, and youth-directed spaces of STEM learning and practice online and in the real world. Youth are also active in publicly calling out and replacing failing systems of STEM learning through radical reimaginations of youth roles and possibilities. This was demonstrated, for example, by Sincere's community organizing to restructure access to basics and access to leisure, as well as his actions to advance his sister's education by teaching her what he learns during the school day in a modified night school.

This section presents implications for multiple areas of practice, some of which are layered substantially with specific youth-authored recommendations for practitioners and policymakers who wish to better support youth efforts to be and become with STEM learning and practice. These recommendations are grounded in our research findings, but they were also supplemented by peer input (Jazmyn, José, Sincere, Amara, and Keke invited peers to assist them in thinking through their recommendations with greater complexity and democratic multiplicity). This additional layer allowed us to draw from a greater range of perspectives, experiences, and expertise. "We're here to represent *all* the children," Jazmyn explained (emphasis hers). What resulted was a wider youth collaboration, intended for a wider range of impacts (e.g., as described above, youth wanted to share recommendations for informal program leaders but also for formal school teachers).

Expanding the concept of youth pathway engagement. Literature on connected learning urges the field to explore and leverage a multiplicity of learning and development spheres across youth lives as resources (e.g., academic, peer-oriented and interest-oriented) (Ito et al., 2013). This is useful but not enough. This study points to additional spheres including the civically- and politically-oriented. Youth are critical thinkers and action-takers in their lives. For example, the five youth in this study demonstrated this through their STEM-rich, action-oriented afterschool projects. Supporting youth engagement in a greater multiplicity of life contexts across their complexity of positionings and relationships in the world can enhance engagement through the co-construction of more complex and transformative learning spaces.

This connects, also, to a need for the field to develop more tools for recognizing the diversity of resources that youth leverage and co-opt towards their desired pathway-making practices. For example, my study showed several instances where youth either dropped out of an experience that the STEM world may deem important because it did not value who they were or what they wanted for their lives (e.g., when Amara and Jazmyn quit their afterschool robotics program).

This study also revealed how youth pursued experiences that were categorized by power-holders as squarely outside the traditional STEM trajectory because this is where they found support and were welcomed. For example, this was demonstrated by Keke's leveraging of time alone in her room watching YouTube videos as immersive medical research and roleplay through vicariously experiencing practices as a surgeon in the operating room. It was also demonstrated in the wide variety of practices youth documented in this study in which they elevated the value of their afterschool STEM engagement as central to their pathways of STEM learning and development, more so than their STEM engagement in school (e.g., not just central to interest and identity development, but central to learning and skill development).

Finally, expanding on the concept of youth pathway engagement must include attention to how youth attend to risk. The field needs tools and approaches for making sense of how youth navigate risk as they seek possible futures, in order to address risk and support youth navigations across it. This need is especially urgent for young people of Color for whom there are greater risks implicated in joining and seeking to transform the powered boundaries of STEM with race, class and gender. Youth in this study made deliberate choices as they thought about who they were and who they wanted to be. For example, Sincere's negotiations about basketball time afterschool that cut into Afterschool STEM Program time was a careful balance that he worked on. He needed adult support to make that balance work. This adult support was a critical pivot to support his desired ways of being afterschool and towards his vision of a STEM future.

Brokering across powered dimensions of practice. Current literature addresses some ways in which adults mediate youth access and opportunities for learning and development. This mediation is interwoven with systems of power that seek to reproduce dominant hierarchies of practice across space and time, limiting youth possibilities. This mediation also occurs across an intergenerational dimension of learning that deserves more attention from practitioners. Adults, in many ways, make up the nodes in an interconnected ecosystem or terrain of life across which youth travel and construct pathways to their desired futures. This includes mediation of not only learning experiences, but also relationships of consequence for youth futures. Youth take this relationship quite seriously, leading to specific recommendations for improved practice.

For youth in this study and the peers they invited into their recommendation brainstorming, enhancing the health of teaching-learning relationships demanded democratization of resource access. Youth insisted that their trust and confidence in adults had to be earned in concrete ways, through a tangible support structure of resource saturation. Adults could acknowledge their high level of STEM learning and practice by supplying their learning spaces with “high-tech resources” like high-speed, free wireless internet and high-speed computers. They also wanted permission to leverage their smartphones as learning resources (e.g., with the reminder that the digital calculators on phones were preferred over the “busted up calculators” more typically provided during math classes).

Many of these arguments for resource equity in STEM education are not new (e.g., Tate, 2001). But their expanded definitions of what constituted a STEM resource challenged adults to expand their resource commitments. Beyond technology, for example, youth called for increasing access to food and clothing in STEM spaces (e.g., beyond surface-level incentives like occasional pizza parties, they argued for fridges full of healthy snacks in every STEM learning space, as a brain fuel supply that was just as important as pens and laptops). For youth, this expanded commitment to resourcing learning and practice in STEM implied greater respect for their humanity. “Buy us what we need, instead of treating us like animals and pieces of garbage,” one peer, Brina, cautioned. Especially in formal school spaces where youth felt more “forced” into working relationships with adults, those adults owed youth the basics they required in order to concentrate and engage in their learning (“We didn’t ask to be here. You made us be here,” she argued).

Healthy teaching-learning relationships also required an adult commitment to communicate openly with youth and seek to learn from and about them. Sincere’s pathway poster offered youth a hack to enhance their chances of developing such a relationship by setting the mature example for teachers. “Be nice to your teacher” was the first step; youth were then meant to invite that adult to offer their support back, in a relationship of mutuality. But he and his peers argued that either party could make the first move. And adults who act first, asking youth about their lives and seeking concrete ways to offer youth friendship, are defined by youth as more highly trusted STEM pathway supporters. Youth layered context onto this argument through shared peer understandings that consequences of singular events (e.g., yelling at students during the very first day of class) ripple out over time and space, producing larger impacts (e.g., distrusting that teacher for the rest of the year). Adults should share with youth and seek ways to be fair, including through shared decision-making processes in which both youth and adult agree to something together. “You have to tell them that you care, [but] you have to also show them that you’re respecting them,” Sincere explained. José added, “You should also respect kids because they’re like your babies when they’re in school.”

In a justice-oriented counter-critique of adult behavior deficits, youth added that healthy relationships also required adults to act in responsible ways that were appropriate for role models. For example, youth did not want to see their adult teachers on the phone during class, a request revealing the hypocritical inequity of power-holders doing exactly what they traditionally forbid students to do. “Take ownership and responsibility for your actions,” José advised.

Positivity was discussed as a requirement for more equitable STEM learning and practice, because youth did not enjoy leaving a learning space with insecurities about what an adult thought of them. This could start with something as simple as adults checking their own moods during activities. Smiles and laughter were important in life, so they were important in learning. “It’s showing me that they’re not mad at me or anything, and they’re engaging with me,” offered peer Anna. Youth added that this went both ways: self-expression through funny faces and funny voices could be welcomed as learning resources instead of criminalized during lesson activities. So could dancing and walking. Physical movement within learning spaces could be supported in the same way that adults sought to support learner mobilities across spaces.

An anti-racist pedagogical commitment was also a requirement. Youth in this study shared nuanced understandings of some ways the different demographic trends between teachers and learners played out in their classrooms in the form of implicit biases against them as Youth of Color. This understanding informed their insistence that every teacher, especially White teachers in racially diverse learning spaces, should learn more about how to be a pathway ally instead of a discriminatory obstacle upholding stale power reproductions. “All races should be allowed to do science, wherever, whenever, with any teacher” Jazmyn argued. Besides, she added, a more justice-oriented embrace of many different student backgrounds in the classroom could benefit teachers by providing them with multiple perspectives they could learn from: “It’s better to learn about new cultures, you know? Step outside the box a little bit.” Brina added, “Because we’re all humans, OK?... Be a part of their family. Try to be their friend.”

Finally, youth offered adults a hack to help them restructure youth-adult relationships in and across learning spaces: become a learner and give youth the power of becoming the teacher. Youth argued that they were ready and waiting to teach adults about their learning and development desired, their lived experiences, and their cultural resources available for adult recognition and leveraging (“What if we have valuable information that you do not know?”). Jazmyn’s opportunity to teach younger children how to use a multimeter and how to think about voltage, for example, resulted in a STEM engagement space of radically different quality that adult program mentors would have been able to create. Her positioning work opened up access for other youth to become more active in the process of learning and practicing STEM, in a way that did not involve or require an adult in a teaching authority position at all. It also resulted in pushing Jazmyn forward along a pathway of STEM community leadership and layered STEAM engagement (e.g., in her construction of a creative circuit game and prize dispenser). When those kinds of opportunities pass adults by and youth expertise is not leveraged, “that’s a waste,” argued José.

Recognizing youth excellence now. We need to recognize youth contributions by the very pathways they work to construct. We do not and should not have to wait for them to be adults to recognize these pathway construction contributions. Youth cautioned adults to recognize the young people in their learning environments as capable STEM thinkers and doers who moved outside of those spaces in complex ways worthy of recognizing and respecting. Youth were not blank slates to be molded to adult whims. They were complex people with ideas and skills to share in partnership. “Don’t underestimate your students,” Amara warned. This recognition of youth excellence includes embracing the diversity of youth backgrounds, communities, cultures, and positionings that they draw on to enhance and deepen their pathway efforts across space and time (e.g, how Sincere drew from his family and friend connections to understand his pathway construction within racial, economic, community, and generational contexts). It also includes paying attention to the ways in which youth engage with STEM towards expanded and transformative visions of a STEM-equipped future across increasing scales of complexity in practice (e.g., in Jazmyn’s visions of a new type of community space to support an expanded range of practices and identities in the future, and in her teaching and design as activism to expand possibilities for the present world).

Limitations

Due to limited time and resources, I limited data collection settings to our afterschool makerspace setting. I triangulated data co-generated with youth through our shared research in several physical settings, but I did not spend a large amount of observation time beyond our three main research locations (e.g., I did not conduct classroom observations to inform this work). This constraint inevitably factored into the degree to which I attained my goal of exploring STEM pathway construction across space and time. Findings likely illuminated more out-of-school mobility partly due to the nature of our focus. But, as I expected, youth continued to include formal settings in their pathway representations, in narrative co-constructions, in critical ethnographic interviews, and in informal/unstructured discussions. This was true even as they constructed those representations in an informal environment. The larger SL+ project's goals were to illuminate informal (out-of-school) STEM pathways and the efforts of youth to construct such pathways. And I recognized formal schooling as merely a small proportion of individuals' actual learning lives (e.g., Bell et al., 2012; & Dierking 2014). Still, I was happily surprised to learn from youth participants about connections they make and see (and disconnections/boundaries they witness, navigate, and even build) between in-school and out-of-school spaces and practices over time.

Additionally, the findings of this dissertation should be understood as reflecting a specific community and reflecting the pathway construction efforts of particular youth within that community. I do not seek causal claims or findings that are generalizable to a larger population. Instead, I sought to learn about the practices and processes of a small group of youth participant co-researchers whom I have known and worked with for years. This critical, qualitative, participatory work can inform the broader education community about new ways to think about, define, question, explore, and represent learning and development pathways, especially in the context of STEM.

Future Lines of Research

This dissertation calls for future studies to explore youth pathways of learning and development over time and space using more multidimensional and critical justice-oriented approaches and methods. Critical participatory co-analysis, for example, offers the field of educational research a new method of analysis that seeks greater mutuality and transparency between researcher and those who are researched. I argue that critical participatory co-analysis can be used across a wide range of disciplines (e.g., human development, learning sciences and educational psychology, curriculum studies, teacher education research, design-based research, etc.).

Future studies could also build on this study by designing and using more multidimensional, dynamic, and participatory data visualization methods, to advance the field's understandings of pathway components in interaction and in tension with dynamic structures of power. Youth shared an interest in a wide variety of tool use to represent and explore their pathways in ever-increasingly dynamic and multidimensional ways. Future studies could employ, for example, virtual reality recording tools, video game design tools, Matlab multidimensional graphing tools, computer programming tools to explore pathways in ways that better reflect the complicated and ever-changing reality of life-under-construction for youth.

Conclusion

Informal STEM has been identified as holding potential to engage youth in STEM more than school science and support youth from marginalized communities to identify with STEM (e.g. Thompson, 2014). Yet, despite literature focusing on how intersecting structural inequalities (e.g. sexism, racism, and social class) contribute to patterns of unequal participation in formal STEM education, less work has focused on equity across informal spaces. Youth expertise about their out-of-school STEM learning pathways can inform researchers, practitioners and policymakers who seek to support such life-wide, life-deep learning, especially for youth fighting against inequity, both in and out of school. This work addresses how informal STEM learning can become more equitable and transformative for youth who seek (or could seek) STEM pathways for their lives.

APPENDICES

APPENDIX A: Youth Participatory Portfolio Case Excerpts

About me

I'm a weirdo. I love art, engineering, and science. Plus, I love

I want the world to know: I'm a rare species of artistic athletic nerd.

I've always grown up drawing and problem solving. I do it so often in my life without even noticing.

I want this portfolio to be turned into **a commercial montage of my life**. Montages are inspiring to me if the right words and pictures are put in. I'd want to include pictures of me doing science wherever I do science, like at school, pictures of art I did throughout the years, and fun pictures of me.

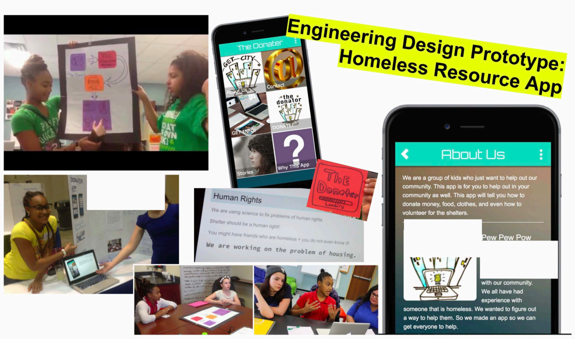
I would also include "Anyone can be a scientist or engineer or artist.", "You can do whatever you put your mind to.", and other inspiration quotes so that people will try to become scientists --- because they KNOW they can do it.

I hope that children around the world watch this, because then there will be a lot more scientists and engineers and artists and more kids who want to actually change the world.

Highlights of Work I Care About

- **Arduino phone caller**
- **Skeeball arcade game**
- **Teaching younger kids**
- **Donator app**
- **Art**
- **Youth Action Council leader**
- **Youth Startup Event**
- **Microbiology**

WHY // HOW



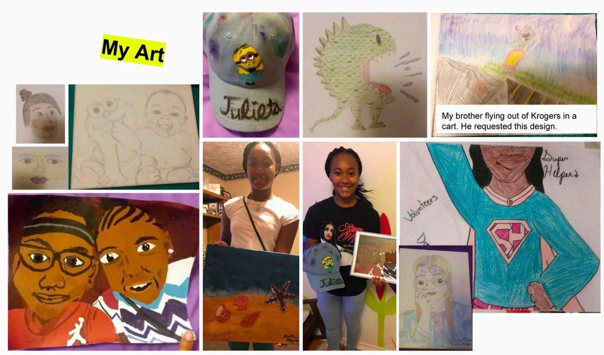
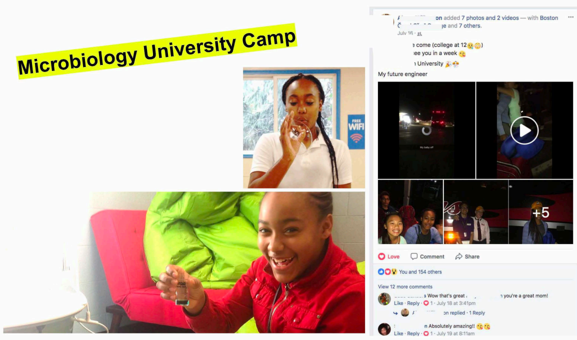


Figure 25: Jazmyn's Pathway Portfolio

Figure 25 (cont'd):



Near Future

One thing that could change the world.

Help out in the community more, go to more competition events, and more around-the-world events that we'd have to travel to do.

Connections

Everything that I have been doing now has already affected my future. The scholarships I have, my appearances in the newspaper, and even A honor roll has affected my future. Giving great paths for me to follow.

Connections: School to home (science projects and parent teacher conferences), / to home and to school, Y.A.C. through , and my mom connects everything

What I care about:

I care about how science is evolved how its expanded and advanced.

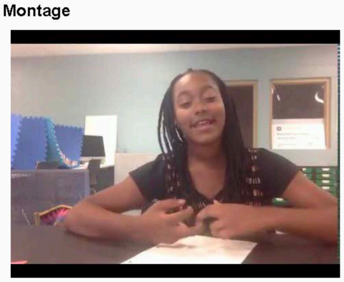
Now there's a lot of inventions and improvements to technology and the world right now. All those are determining how our future will unfold.

I hope people will learn that you shouldn't be afraid of what you want to do especially if others judge you for it.

You can be whatever you want to.

People should be able to do whatever they put their minds to and not let others take control of their life.

Intro to Pathway Montage



JOSE'S PATH(S)

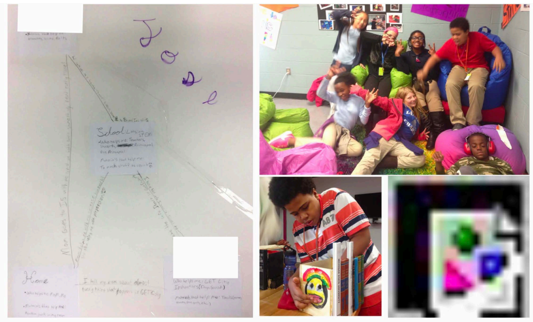
There are different paths to each destination in life.

I want to tell you about my paths I take and the paths that you and everybody else has to take. You have to choose the right decisions and the paths to take are not always the paths that you choose. It's not always a straight line. It has twists and turns. But it's worth it if you make your dream come true.

The point of telling other people about these paths is to make sure you and everybody else make the right decisions.

It's important to help you people watching and reading because I worry that if you don't read or watch the stuff I put on here, you might take the wrong path unless your parents are teaching you right.

Look out for the twists and turns because some might be dangerous!
You might have to... risk stuff.



Past to Present to Future

At age 5 I was just playing around with science. Right now I'm tinkering with it. I'm making it more complex. And in the future I'm gonna be mostly mastered in it. Well, "mastered" in it. I'll be way better at making it and discovering more about it. Right now I'm just learning way more about it. I'm learning a lot about it and tinkering with it. At 5 I was just playing around with projects my brother made.

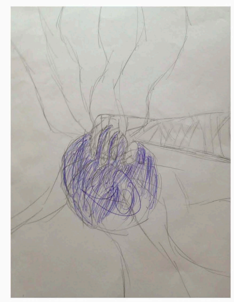
Thoughts about Science

In science, there is more than one person doing the job. There's always teamwork included in it. You can never do it by yourself even if you try.

- "If you fail once, you have to try again. If you fail twice, *try try again.*" The two tries mean "including other people".

Times I think about science:

- When I wake up: TV generates the release of carbon dioxide from the power plant. The oatmeal makes me think about science because when you put too much water in it, you just put a paper towel over it, and wait 5 minutes, and it's perfect. It looks like it absorbed all the water. But don't put too much water in, just a little bit, to wear you can still see the oatmeal. I don't know how something so dry absorbs so much water. I want to find out. It's probably just like how cereal does it. You know, how corn flakes absorb milk, where it's all dry but then it gets wet, and the corn flakes look bigger.
- And when I go to bed: Why can't i remember the moments before I fall asleep? You know how you try to stay awake but then you fall asleep and forget everything about when you went to bed, but you can remember the stuff you did before you went into the room.



Future

I wanna be the master of my own bionic army of gerbils. They will be very cute but deadly to my enemies, all the people who wronged me life. Including a stranger online, a hacker, who took 9,000 Robucks on my friend's Roblox account.

It will be very easy to track him down since in the future I will be a computer genius. I will hack to find the hackers. I'm gonna probably be one of those CSI or FBI agents that can track down these hacker people for doing illegal stuff, any kind of hacking, for bad use. I will be the world's greatest hacker-tracker.

I'm gonna make my own supercomputer using solar power because my office is going to be made of indestructible glass and my solar powered computer will be super. It will not have any carbon footprint like carbon dioxide produced which can cause pollution.

My office is going to have a lot of tech and I'll be a successful worker to probably own a penthouse and my office will be in that. I will have a lot of trees around it to absorb carbon dioxide and release oxygen.

Future

Goals: To discover a new element and have it named after me. Some of the smartest people in the world discovered new things like an element and they got put on the periodic table.

I want to be known as someone that did something no one had done before. I have not been known a lot. I want to be known as someone that will change the world.

I want to find something that's helpful and useful. It'll be named after me. I'll put it down on my family's name. Not a lot of stuff is in my family's name. So when I die, at least I'll be a great doctor and someone that found an element. And if I don't I have other stuff planned like the bionics. So I'll die as one of the best. As one of the best people that were alive. I just want to have something for my family to remember me for. Like, I know they'll remember me, but I want some more for them to remember me about.

I'm leading towards either a professional pianist, professional surgeon, or a robotic professor.

Present

Right now I just wanna focus on my academics so I can build up to success because success isn't a straight line. It's a squiggly line that never ends. Next week I'll meet with a tutor for math and we'll be there 2 days out of the week. I didn't do well and I got a failing grade in math so my mom got me a tutor so I can strive to get better in math. It's important to me so I can impress my mom and stretch out for success because I'm a Hope Scholar.

I can't get really bad grades or I'll lose my scholarship for college. I don't know if I would or not, but just in case, I want to get all good grades so I can keep my scholarship. You can't move districts or you'll lose the scholarship. And you have to go to a community college for 2 years and then after those 2 years I transfer to a Michigan University. You get free dorms and everything.

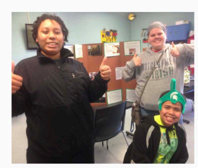
I'm a very respectful student at times. If you mess with me I'll snap. I can control it, but sometimes I'll snap. It gets me in trouble sometimes. Sometimes I'm a good student because I listen to my teammates' ideas and we all work together as a good team. I'm a good engineer because I'm really creative and I like making stuff, like drawing and building stuff. You have to make blueprints to make stuff and build stuff as a professional engineer. I'm good at building stuff and drawing, so that will help me as a professional engineer, so I can professionalize in building and making blueprints.

Present in

I come all th excited, and I'm also mad when is not at the Club because I usually have nothing else to do and I like being in here, working with friends in here.

We all listen to each others' ideas and we work together as a team by talking to each other of how the plan is gonna go down and we also prepare each other for what's gonna happen. Like, say we're building something, like a game or something, and it keeps breaking, so we have a plan to back it up when it breaks. And when we run out of plans, we just make a better one, and we make another one in case that new plan fails too. If that new plan fails, we're just going to keep on going until we succeed.

Like they say, if you don't succeed the first time, try try again. I do that in engineering and building. Usually you're either making something complex or inventing something in engineering. In building, you're just making whatever you want, even if it's already made and existing. But in engineering, you innovate too.



My top 5 moments in science

#5: Learning it at school

#4: Doing paper circuits

#3: Dealing with green energy

#2: Working in

#1: Doing Chemistry

My top 5 worst moments in science

#5: Spilling test tube water

#4: Spilling chemicals

#3: Chemical reactions

#2: When I get falsely blamed

#1: When I get in trouble

Connections

My locations are connected by people and how they help me. Like how my mom helps me with homework at home and that connects to school. And how I take knowledge from school, and how I also take from school and bring i . And I ghts and leave school to sights information help re. It b because I got interested because of Insights. And fo will help me succeed and surpass all others. Bill Gate, Stephen Hawkings, Albert Einstein. They are all really smart people. When I grow older, I'm gonna be smarter because the info from will help me get there. They teach me a lot of useful stuff for my plans for the future, like being a son, making bionic animals and genetically modified animals.

I really don't go anywhere except fo nd school. So I don't really do science anywhere else. But when I take the trash out, I throw it far into the trash can so I don't have to walk over there, so I think about angles and I have to measure how it's going to land in there when I throw it, so I don't miss. We have to figure out the physics and angles of how we're gonna build stuff in that's connected to how we work in ay: What helps you move from one experier er?

Figure 26: José's Portfolio

Figure 26 (cont'd):

What's still missing

Anybody that could help me get there. And job offers would help. I'd want to start that now. As an intern.

I would like to learn what it is like at a company like a doctor's office or music instructor of inventor. Or I'd want to be a desk person at a doctor's place to look around. I would see how things go around there and see what there is placing in my future. How it relates to my future. Probably 3 years from now.

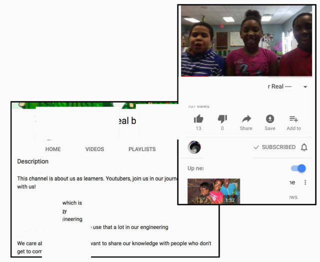
The mentors I have right now could probably help me through all of it but I still want more to help me out. Like in college I could be in a dorm, and they could be a student too. They could be always next door in the dorms. Always helping with like, with homework and stuff. If I'm having trouble they can most of the time have my back.

My mom raised me to be the best. I wanna be the very best, no one's ever k jet a 4.0 I'll get scholarships and stuff and it'll progress me more. Like if I get a scholarship f . could probably do 6 years there. But I'll probably go to U of M for my doctor's degree because they've got a better doctor program to be a bionic surgeon. That means get all A's and study hard, pupper!

Taking Action Against Trump for STEM Education

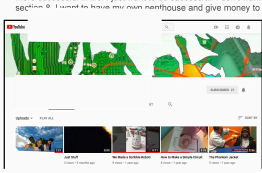
Kids need to learn what we do and fight against Trump because Trump might take away money from the B s Club, from nd from which take of the science.

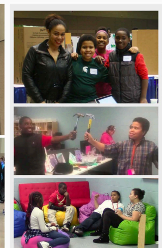
For example, the engineering teacher at my STEM academy, wasn't getting paid enough and she got a better job somewhere else so she left and we didn't have engineering anymore. So now it's not a STEM academy anymore, and it went back to its original name. We are running out of money in our schools because of Donald Trump and other politicians like Mike Whachumacallit Pence, and Mike Bishop, our Republican representative. I like Democrats because Hillary Clinton was a Democrat and Bernie Sanders was a Democrat. They are better than Trump because they don't build walls and they're not against Mexicans or other races.



Our Solution: Find us on Youtube

Kids should take action so they can fight for their schools. We want our YouTube educational channel to make money so we can take some and put it into our education programs. We also want to use the channel to spread our knowledge to people all around the world. For people that can't go to school or are home schooled, or are not learning in school because they like watching YouTube better than learning in school, they can watch educational stuff on YouTube because we explain it better than the teachers. The teachers don't show what they say that much, and when we ask what they mean, they just say it and don't show us. Then we ask again, sometimes they don't listen. If they don't listen, then then we won't know the knowledge that they're supposed to be giving us. It's important for us to have the knowledge so we learn more and can be more successful in life. I just want to be successful. I don't wanna be living on the streets or living off food stamps and section 8. I want to have my own penthouse and give money to charity and do cool science stuff like build a rocketship.





José with his mom (left) and his best friends & Youtube channel project team members (right).

José (right) high-fiving hammer-style with his best friend (left).

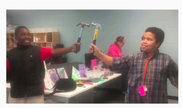
José brainstorming with his friends (left) and STEM afterschool mentor (right).

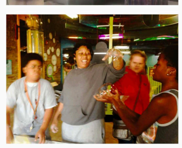
Mentoring in

mentor in training (MIT), in one of the best programs for engineering and green energy. It's very fun and you have to be hardworking also. You need to be focused, you need to be working hard and you need to learn how to respect other people's ideas is like where, if you have nothing to do then you can go ause it's all about science, some people's favorite subject. Shout out to the science lovers.

And then Day and Sarah are the instructors and also Angi they're like the rarest teachers in the world who actually understand the most. So that's the main reason I come to nd to chill and do work. A lot of teachers, they don't listen or stand what you're trying to say. Some teachers actually get up and teach you stuff. Day, Sarah, and Angie get up and teach you to help you learn more.

So that's why I'm in here, to help me learn science more thoroughly.

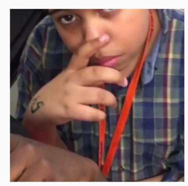




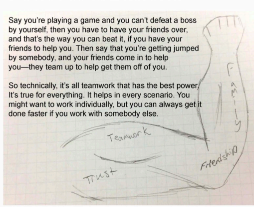
What this says about me

I think it says that I've really come far as a hard worker and I've achieved a lot. I'm good at learning and I know that I can grow even more. I'm gonna be an awesome scientist or engineer. I'm gonna be cool and awesome. I am now but I'm gonna be a more awesome one.

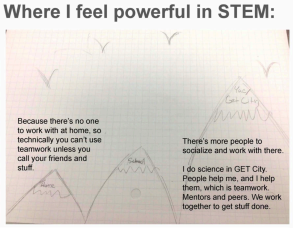
As a member of the community and as a leader? Well I'm born to be a leader. Because I said so, and I'm a hard worker. Sometimes I can be a leader but sometimes I can be a follower just to get the information I need more to be a leader. Gathering information from another leader, like I'm an undercover boss or something. And it says that as a member of the community, I stand out. Because everybody knows me. I can walk around the club to people I don't know and they'll say, "Your name's Jose. I know you." People say it all the time. Because I'm popular and I stand out.



Power is teamwork.



Where I feel powerful in STEM:



You'll always need help sometimes. You can't do everything yourself. There's always a time at life when you're low, and then you need someone to help you out. Like you can lose your house or get evicted, and you need to stay over at your friend's house or your family's house. You can't use one single person to improve a problem in the world. You always need a big group or something. You can't impeach Donald Trump by yourself. You always need a group of witnesses or something. Some people get their power from privilege. But they could always take those privileges away.

What this says about me

I'm a nice guy and I'm smart. I have high goals that I need to achieve. The pathway to success will always work if you work hard all your life and save your money and be wise with it too. I'm a nice caring guy and I would do anything to protect my fellow peeps. My identity is, well, you heard the rap. My identity is somewhat of a procrastinator. When I don't want to do work, I won't do it until like I get yelled at [laughs]. That's not a bad thing because if you do it later on you are forced to get it done quicker which makes you learn it faster. I don't know if that's knowledge but I think that would be helpful because you're getting it done faster which is like shoving it all into your head trying to go through it and understand it.

I'm a fast learner. Me fast learning made me more advanced and made me accomplish more in e home and show my mom and my mom teaches me sometimes too. Like, she tells me more about the stuff I learn. And I take that knowledge to school which makes it easier to learn in school, which makes it faster. And at nat knowled ugh school t

I want you to know

I'm a hardworking student, so have a good first impression of me for my reputation. I'm going to college and for stuff and achieve it, so it will affect you in a good way with good karma. something out of it and I could use that to buy a piano. You never know, I ano teacher or a professional pianist like Stevie Wonder. Your accomplishments can change your future. Like the contest and then making a YouTube channel. It shows that I can be a hard worker like all the time. And it shows I can achieve high stuff.

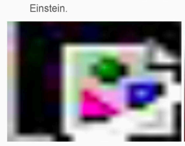
It's all about karma. I'm a good karma bringer guy. I bring good karma. I do good things. It helps me out because I got a reputation. The better reputation I get the more help I'll get and the better my team will do. People will want to work with me more. If you do more good stuff, people will help you more. And that's good karma. You can't just have good partnerships with people you don't get along with. It'll be better if you pair up people with people who will get along and be good working together. I want that in my future too.

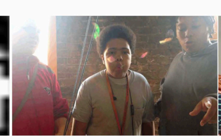
Stay in school and aim high. Always work with other people. You can always make it if you choose to look up to someone. Always be inspired by something. Be inspired by me. (I'm pretty sure you probably will be, but I'm just saying that because I want you to.)

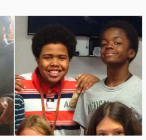
My Project Goals

My ultimate goal would be to learn what can come out of this. What we can do with this. I would want to affect everyone that wants to learn. Everyone can learn from this [project]. Affect everyone. I want to make an impact with this project, but I don't know what kind yet.

I would want everybody to see it because I want everyone to know who I am because I am a legend. Like the song: "If I die, I'm a legend." So I'll die as a legend and everybody will know my name. I'll be like Alexander Hamilton. Everybody knows his name. And they know Bill Gates, and they all know Albert Einstein.







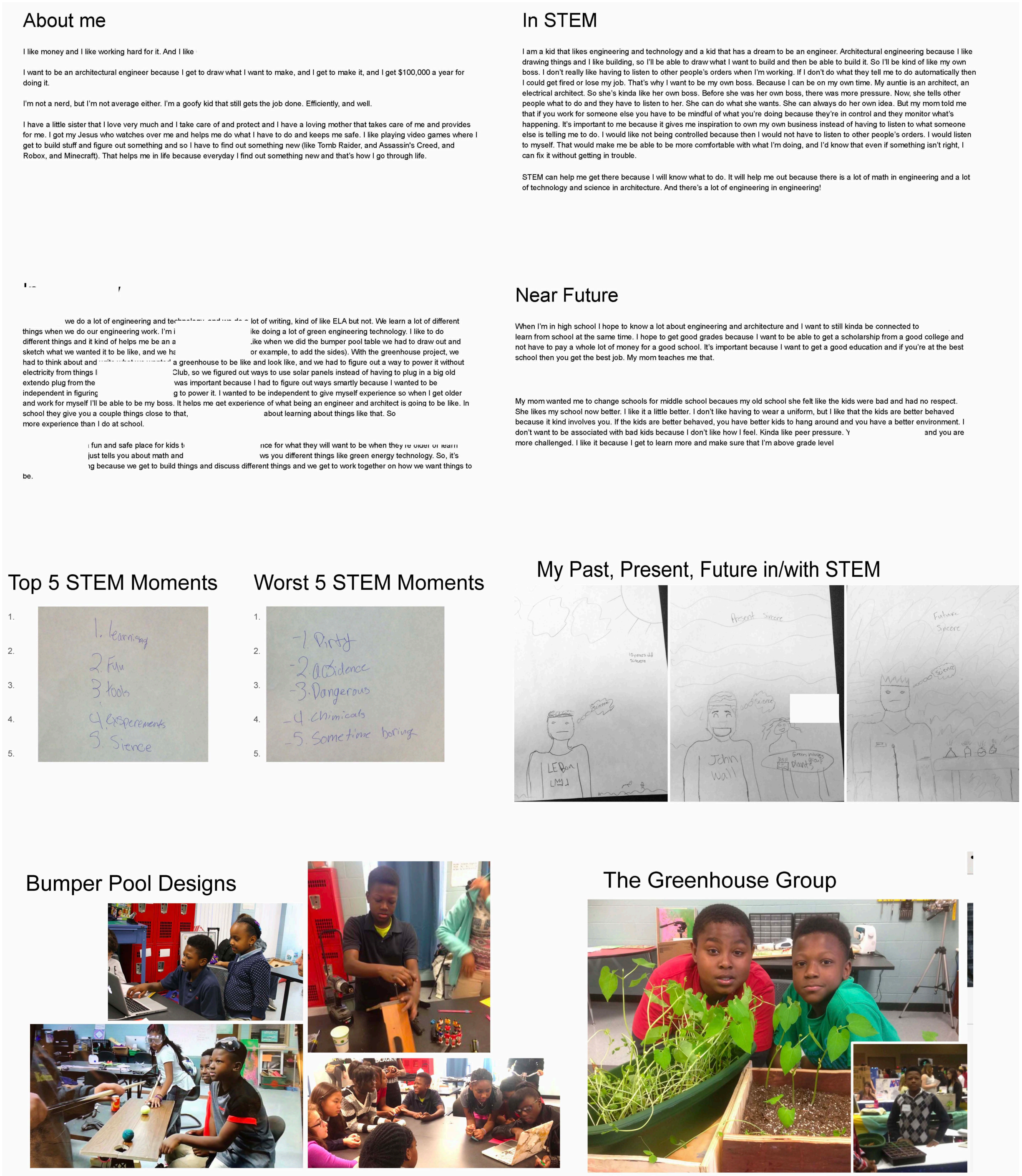


Figure 27: Sincere's Portfolio

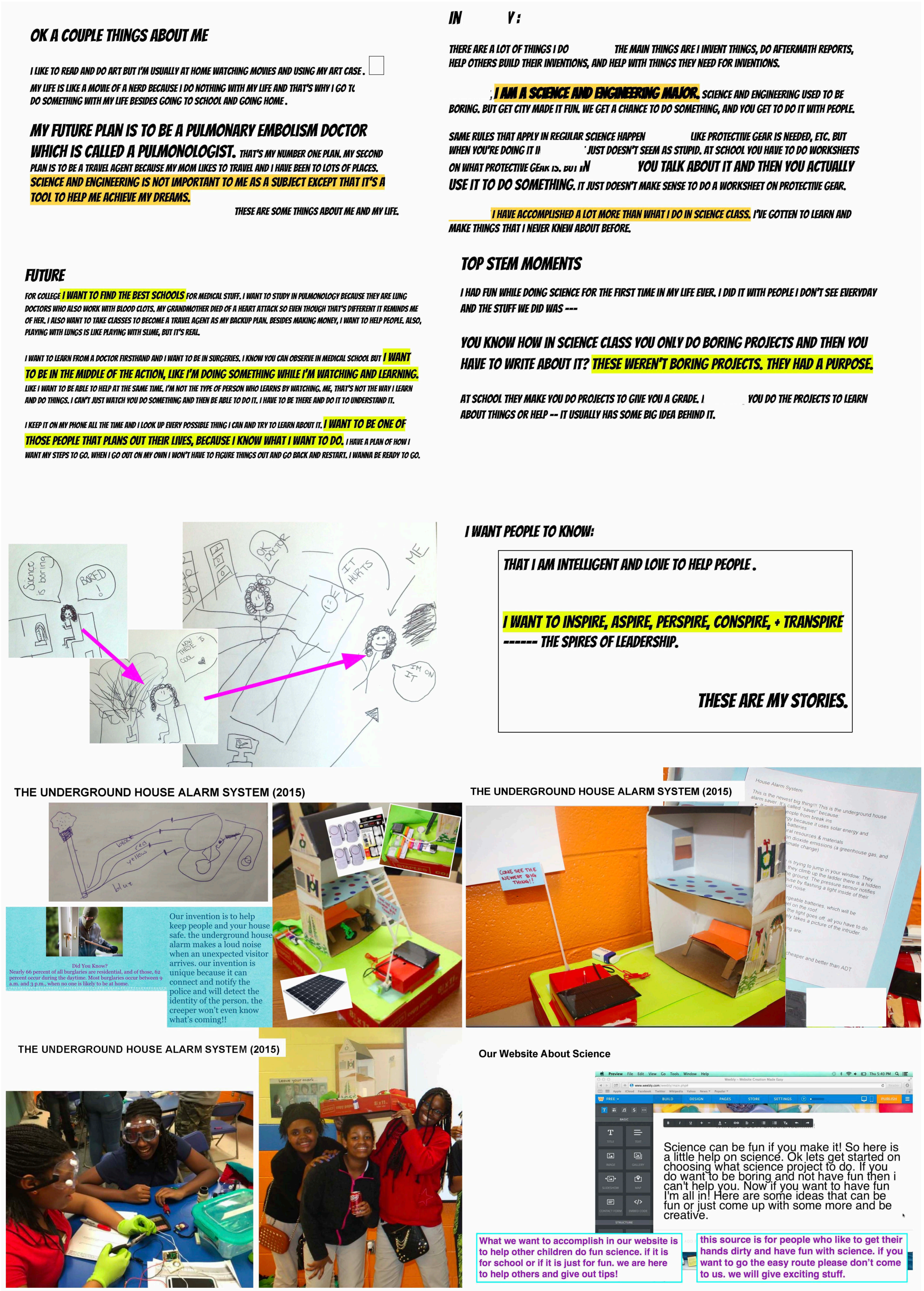
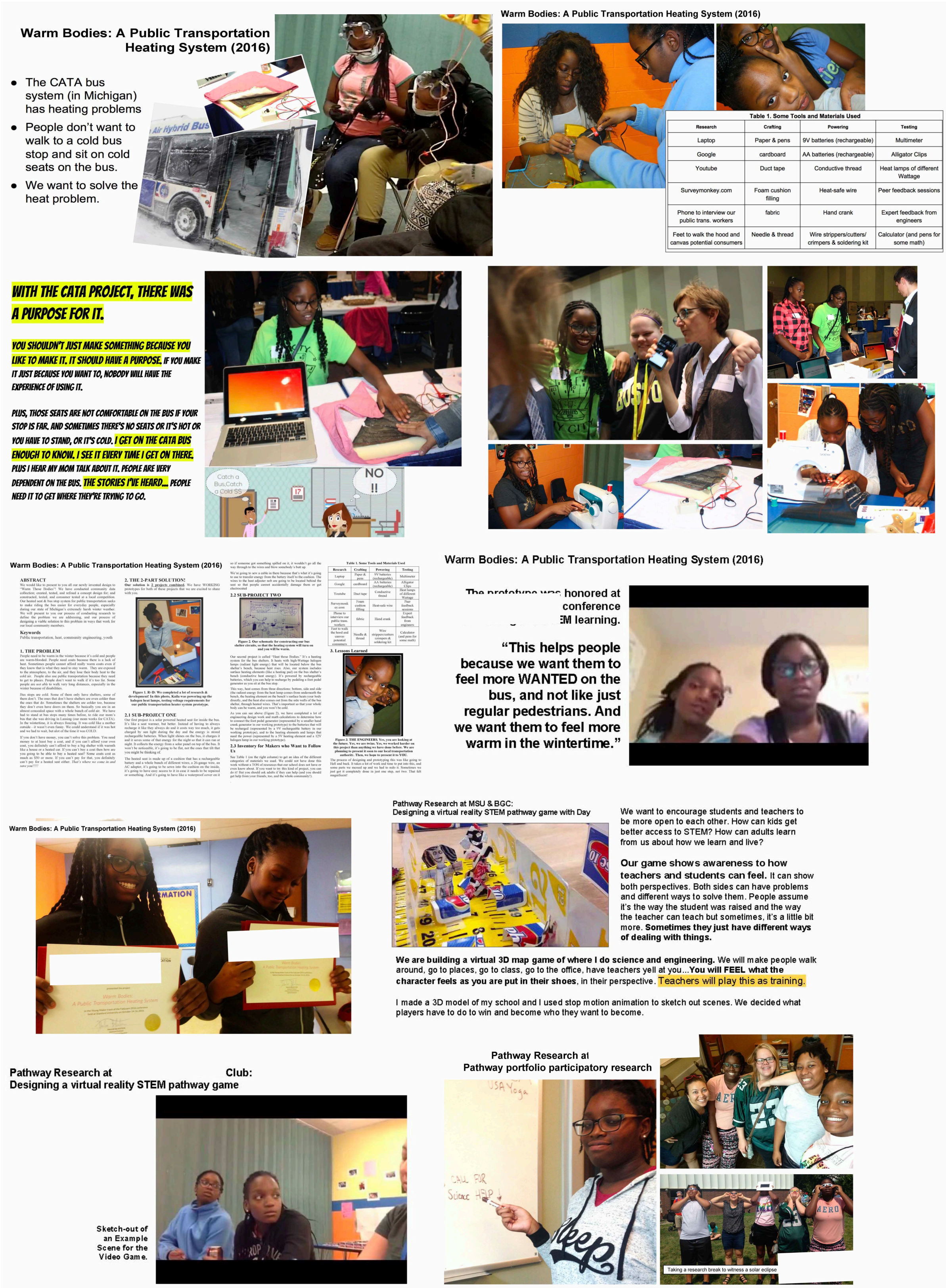


Figure 28: Amara's Portfolio

Figure 28 (cont'd):



Keke

Welcome to my year book!!!

About Me:

I am smart and creative. I do like science but not the kind in school. I like chemistry and biology and engineering. I am awesome in science and engineering. I learn new things. ***I am very creative and weird.***

I'm weirder than most people on the planet. I don't act like other people. I act nice. Other people act disrespectful. That makes me very different. Also, I stare at everybody to observe them because it's very interesting. I'm very observant.

It's important for people to know that ***I can be serious with what I do.***

A circle is so unique technically.
Everything else has sides.
A circle, it's just round, no sides.
It's very bold.
I am very bold and different just like a circle.

I'm a superhero. You'd come to me to save somebody's life.

Purpose

My goal for this project is people learn that science is fun and interesting. ***I hope that people will learn more about science and engineering by learning about my experiences in it***, through this pathway project. People should know more about science because everything is made of matter.

I really wish that i had a better school system. It would be cool if the school had better school books and science classes. It seems like everyone doesn't take science because they think it is stupid or they fail because they don't like it.

In high school, I want to do some college classes. There's a program where you can do that. I would want to learn how to be a doctor. Like, I want to learn about the human body and its anatomy. I think a lot about graduating because I want to pass all my classes so I can become a pediatrician. And I really want to do an internship at a hospital and then become a resident there, and then a doctor.

My Future

I want to be a pediatrician because I want to help the kids i can help! But i am good at hair so i might do hair ***when i am not saving the world as a superhero***. I want to help kids because when I was born I was turned around as a baby and a doctor saved my life. They had to go in and turn me around because I was coming out the wrong way. If the doctors didn't know what to do I would be dead.

Doctors help kids. I always liked kids.

STEM Pathway Resources

I talk to myself and to my sister about science and engineering.

And I talk to Wikipedia. ***Me and Wikipedia are friends.*** Like, Wikipedia tells me like, "oh, you should do this." And I'm like, OK Wikipedia.

You know how they have like, pamphlets that you get from a doctor's office? When I go to the doctor I take them all.

And I use YouTube to watch videos about what a pediatrician actually does.

In

I am active because I do stuff. I eat, I work, I type, I write, I look, I feel, I see, I make things, I help people. I made a lot of stuff. I have a website. I also have inventions too.

I feel like a nice persor ***because I help people with the inventions I make.*** With the website, I wanted to help people learn more about science and what science does. Not a lot of people like science. They think it's dumb. I think science is cool. People can try it out and see that it's cool, just like I know it is.

Message to Adult Researchers & Educators:

Please be more in depth with what you're doing.

Take actions. Be more focused. Care more.

You guys wander around like it's a whole party. You should be working harder to change the world for kids. Be a superhero, save lives.

What I'm doing makes people better off. You need to know. I want to show that you don't always have to just be the one that's in college to know what in the world science is. *There's kids like me out there doing science right now.*

What this pathway portfolio says about me:

It says that I'm pretty damn smart. A lot of people, they don't really do anything. They don't have like, things to do. And people don't really like science, so…you know. It's just like, being that one weird person you know that's in science. I do things that other people don't do.

I'm very outgoing to do things. I'm very adventurous with people and with learning. I'm a superhero. Superheroes save the world. I would be a good research scientist, but I want to be a pediatrician.

Everything I've done so far, people don't usually start this until their 20s. For me to get a head start, I'm more advanced. I'm ahead of the game. I'm pretty awesome.

The Sexual Assault Prevention Prototype (2015)

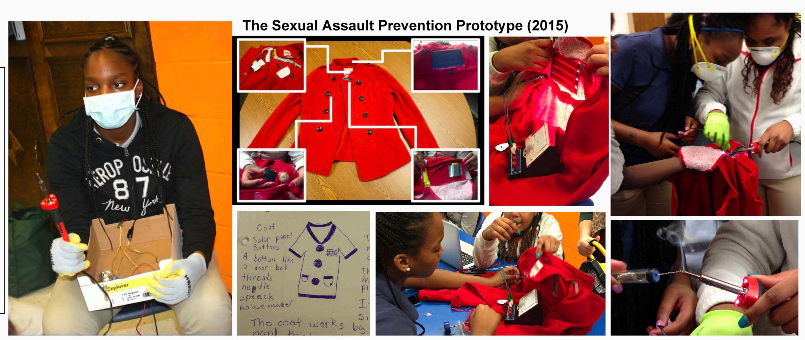


Figure 29: Keke's Portfolio

Figure 29 (cont'd):

APPENDIX B: Youth Pathway Portfolio Interview Protocols

Part 1: Portfolio Co-Construction

I will provide an overview of a portfolio (youth-accessible), and a clear description of what they will produce and how. Questions guiding this:

1. How do youth experience and describe ISL experiences? In what ways do core demographic variables (e.g., ethnicity, class, gender, geography/ location, context) shape those experiences, making them equitable or not?
2. In what ways and under what conditions are youth supported in connecting ISL experiences towards the development of equitable and transformative ISL pathways, and for whom? What makes pathway development successful (or not) and with what outcomes, e.g. content, practices, agency, identity?
3. What tools, resources and strategies contribute to youth efforts in path-making?

As participants, youth will co-construct "pathway portfolios" with RPP teams. Each portfolio will be organized in three sections:

a) "Getting to know …" (e.g. background, interest/ participation in STEM, community asset mapping, science capital),
b) ISL experiences (e.g., pictures of experiences/artifacts youth feel represents their ISL experiences and movement across experiences, video diaries filmed on reflective prompts about the nature of ISL experiences, etc.), and
c) Resources/People (e.g., text or video on who/what support their work).

Portfolios will be co-constructed with RPP teams within an interactive password protected wiki format, enabling easy multi-modal construction over the course of about 10 weeks (in 2-hour group meetings housed at partner sites, after-school or in existing programs). Session will take place March-June 2017. Sessions will gather multiple ideas, perspectives and relationships to co-guide the process.

Week-by-week Plan. These questions below are conversation starters. Each group member will have a chance to share uninterrupted. Then participants can question each other.

Week 1. Introductions: Name, why you joined the Pathways Portfolio Group. Share stories from your science background section of the portfolio: Select one of your stories documented in the portfolio to share with the group. Share images/text/audiovisual from the portfolio. Describe what it means to you as a science person.

Weeks 2-4. Share stories of **experiences** that made a difference to you in your science pathway. Each week, select one of your stories documented in the portfolio to share with the group that helps to show the experiences that have a made a difference to you in your science journey. Share the images/text/audiovisual from the portfolio. Describe what an empowering ISL experiences feels like, looks like to you. Describe what you do during an empowering ISL experience. Describe what outcomes matter to you during an empowering ISL experience. Which ones seem the most important to you? Help you to move from one ISL experience to the next?

Weeks 5-7. Share stories about the **people** who have mentored you in your science pathway. Each week, select one of your stories documented in the portfolio to share with the group that helps to show the people who have helped you in your science journey. Share the images/text/audiovisual from the portfolio. Describe what being a good teacher/mentor in informal science means to you. Which ones seem the most important to you? Help you to move from one ISL experience to the next?

Weeks 8-9. Share stories about the **resources/tools** that have helped you in your science pathway. Each week, select one of your stories documented in the portfolio to share with the group that helps to show resources/tools which have helped you in your science journey. Share the images/text/audiovisual from the portfolio. Why did you pick these resources? Which ones seem the most important to you? Help you to move from one ISL experience to the next?

Week 10. Reflections on the 10 weeks. What ideas stood out to you? Are there any other stories you would like to share?

Optional Round 2 (6-8 weeks). We will follow the same pattern of asking questions about experiences, people and resources/tools.

Part 2: Individual Portfolio Think Aloud Interview: Youth Interview Protocol

The purpose of this interview is to elicit youth narratives about youth/RPP learning, engagement and participation in ISL, and the practices that support it.

I. Tell me about your portfolio.

Walk me through what you have included in your portfolio and why.

II. Reflect for a moment on everything.

Reflect for a moment on everything in your portfolio you just showed me. List your 3-5 most "favorite" things. Favorite might mean you are proud of this work, it shows something important about your participation or what you accomplished, or you just are excited about it. Let's walk through each one of those artifacts.

III. Reflecting on each of the artifacts.

From your list above:

- What is this an artifact of?
- When/where is it from?

- Why did you include it? Why do you label it as one of your favorites?
- What people helped you in the experience represented in your artifact?
- What does it tell us about you as a “science person”?
- How were you supported by your peers/teachers in creating this artifact

IV. Stepping back.

- What does your portfolio tell me about your science pathway?
- What kinds of experiences are in your science pathway?
- What people are in your science pathway?
- What resources are in your science pathway?
- Where would you say your science pathway is leading? Has that direction changed for you? If so, how?
- What roadblocks have you encountered on your science pathway?
- Who/what has helped you to navigate those roadblocks?
- Is there anything else you want us to know about your science pathway?

APPENDIX C: Artifact Interview Protocol

The purpose of this interview is to elicit youth narratives about their learning, engagement and identity work in Making. Youth should come to their interview with their Making Portfolio (if possible) and/or select select 1) a “making artifact” (e.g., their prototype) and b) items in support of that artifact (e.g., sketch ups, notes, video/audio, etc). Materials include audio/video recorder, markers, notebook, prototype, and anything else participants select as reflective of their work. Three categories of questions include: Understanding the artifact, Participation & Engagement, and Knowledge & Practices.

Understanding my Artifact

Tell me about your artifact [invention, design, prototype, etc.]

- What is it? What is it used for?
- Who uses it? When? Why?
- What is the name of it? How did you come up with this name?
- Anything special I should know about it before we talk more about it?

Tell me a little more about the problem you were trying to solve with this artifact?

- Tell me about the problem you are trying to solve (examples/stories/experiences).
- How did you decide or figure out this was a problem you wanted to solve?
- What needs does it address?

Tell me about how your artifact works

- Have youth demonstrate the artifact and walk through how it works
- Slow down the explanation process to go through the different parts of the artifact
- What works? What doesn’t? What do you still need to figure out?

Supporting materials:

- Walk through each piece individually (if the youth brings in more than 3 pieces of supporting materials, ask them to pick out their favorite 2 or 3).
- Why did you select these pieces of work to share with me? Tell me about each.
- When did you create this in the process? How did it help your final artifact?

Participation, Engagement, Roles

"We're going to go behind the scenes. I want to understand more about how and why you made this piece of work. Start from the beginning. Tell me as much as you can remember about making it. I'll map it out as you talk." [co-construct map on chart paper]

- How did you start off? What were the "big steps" you took along the way?
- What surprised you along the way? (How something worked or did not work? Data that you gathered as part of your investigation?)
- Who did you seek feedback from for your initial feedback cycle (peers, club staff, family). Tell me how their feedback influenced your design
- What investigations/experiments did you do? How did it influence your design?
- What role(s) did you play in getting feedback? What role(s) did you play in these investigations? What role(s) did you play in building your prototype?
- What were your moments of discovery along the way? (i.e., consumers wanted headbands, Bob's battery comment) Aha moments?
- What were your biggest struggles along the way?

As you ask these questions, try to determine how much support the youth received from a) mentors, and b) peers (not in their group, if this is a group project) in creating the artifact/at each step.

Resources.

- What materials did you need to do [X]? Did you have what you needed? Why?
- Could you have done this at home? At school? Or have you ever done anything like this at home? At school?
- Could/would you have done this project by yourself (if it was a group project)?
- What would you change about it now, if anything?

Meaning/Value.

- What do you think this prototype or invention says about you? As a learner? A scientist/engineer? Something else?
- What do you think others would say about this prototype or invention if they got to see it? (who, what, why?)
- What are you most proud with respect to this prototype or invention? Why?

Developing STEM Thinking.

Prior & Current Knowledge & Practice

- What did you know about [XX] before you made your prototype? Where did you learn about it? Do other people in your family know about [xx]? How do you think they learned about it?
- Can you think of some examples from home where you learned about [xxx]?
- What new knowledge did you have to learn to do this project/artifact well? Where did you learn it? How?
- Ways of being scientific. Have students circle the practices that they have taken up as a part of their investigation. Have them start the ones they feel they have gotten good at. Ask them to tell a story about using that practice(s).

Science and Engineering Practices

Which practices below were most important to you? (prepare handouts with list of practices below). Have students circle all of the practices in which they engaged. Then ask them to star the ones they think they used the most. Then go through each of the starred practices, and ask: a) tell me about when you used this practice:

- What were you doing? Why?
- How as it helpful to your project? How did it make you think about your project?
- Did you need help with the practice? If so, who helped you?

NGSS Science/Engineering Practices

- Asking Question / Defining Problems
- Developing & Using Models
- Planning & Carrying Out Investigations
- Analyzing & Making Sense of Data
- Using Math & Computational Thinking
- Constructing Explanations; Designing Solutions
- Arguing with Evidence
- Obtaining, evaluation & communicating information

Being a Community Science/Engineering Expert

- Sharing my science/engineering ideas with others
- Listening to other science/engineering ideas
- Connecting my ideas to my life
- Connecting my ideas to my community

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