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Mycelium as metaphor: a case study of a community-based participatory research project with an oil refinery impacted community

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Methods: Standard approaches to research with communities impacted by environmental injustice often prioritizes institutions as experts rather than those with lived experience. Community-based participatory research (CBPR) emphasizes equitable and meaningful participation of community members, stakeholders, and researchers and has evolved into a widely accepted interdisciplinary methodological framework for research addressing health and social inequalities. In this case study, we use a “talk story” research dialogue between principal investigators and partner organization leaders of a non-profit that serves communities impacted by an oil refinery’s environmental pollution to reflect on relationship and implementation strategies used in the Air Quality Investigation for Research Equity (AIRE) project. Talk story utilizes dialogue and shared personal narratives to generate meaningful data through a relational process. Rooted in principles of Indigenous story work—including mutuality, reciprocal exchange, and deep relational accountability—dialogues center on a particular question or topic but unfold conversationally. Using our talk story dialogue as data, we conducted thematic analysis to illuminate the relational and concrete strategies that led to successful implementation of this CBPR project. We use mycelium as a metaphor for describing intricate mutualistic relationship-building, collaborative design, and implementation processes throughout the AIRE project.

Results: Thematic analysis of the talk story dialogue revealed 5 primary themes describing the relational strategies we used from design through dissemination: 1) Rooted relationships, 2) Cultural humility and responsiveness, 3) Destabilizing power inequities, 4) Impacts of the legacy of trauma, and 5) Long term relational commitments.

Discussion: Documenting and reflecting on this CBPR project, we illustrate how embodying principles of CBPR through prioritizing building relationships of trust over time and centering community members impacted by air and environmental pollution at all stages of the research process can lead to successful research

implementation and achievement of mutually beneficial shared goals. Our aim is to use this case study to develop a template of relational strategies for scholars working with and for communities impacted by environmental injustice.

KEYWORDS

air pollution, environmental justice, environmental racism, Latine, community based participatory research

1 Introduction

Fungi support regenerative ecosystems by breaking down pollutants such as oil and pesticides, binding heavy metals and radiation, and filtering water. Mycelium acts as a fungal root system with underground, web-like threads called hyphae connected in intricate communication and nutrient-supply systems. One of nature's most resilient organisms, mycelia thrive in moist, nutrient-rich environments, breaking down waste, nourishing surrounding root systems and supporting healthy ecosystems (Sheldrake, 2020).

In this reflective case study, mycelium serves as a metaphor to describe relational processes in a community-based participatory research (CBPR) project on environmental justice (EJ) in a refinery-impacted community. Mycelia sequesters carbon and remediates environmental pollution. Symbolizing our approach to this collaborative project: that we are grounded in deep-rooted relationships; part of an interdependent circle connecting social and natural worlds; and facilitating communication of care and mutual aid extending outward in intricate interconnected networks that nourish and heal. We also see ourselves as threads, much like hyphae, within an interwoven community working toward regeneration.

Mycelium can be mutualistic, fostering symbiosis, or parasitic, extracting from their surroundings. For this case study, mutualistic mycelial systems best represent our relationship with Cultivando, our community partner organization, conveying the relational nature of our CBPR methods and story work approach which fostered reciprocal, rooted, mutually beneficial connections. This metaphor also reflects Cultivando's organizational structure, which relies on the promotora model of education and empowerment (described below), where community liaisons 'web out' networks of communication and education around environmental and social justice issues, nurture mutual aid systems, and hear community members' needs and concerns. Like polycentric power in mutualistic mycelial networks, both our research approach and Cultivando's structure seeks to level power hierarchies, enhance social connections, and build 'rootedness' to place and community (Cantor et al., 2018).

This case study illustrates our research framework, emphasizing our relational commitments to community goals within the Air Quality Investigation and Research for Equity (AIRE) project. We first provide a brief background and history on CBPR, discussing its strengths and challenges. Next, we summarize environmental conditions affecting the community involved in the AIRE project. We then illustrate how we established and maintained a long-term relationship with Cultivando and impacted community members, ensuring ethical integrity and relational accountability throughout the project. We also describe our strategies for overcoming common challenges of CBPR, offering a template for other scholars and

communities engaged in community-based research related to environmental (in)justice.

Unlike traditional researcher-led approaches, the AIRE project was stewarded by Cultivando and the community, with our role focused on collaborative support in design, implementation, and analysis. With data collection on the full research project complete, here, we reflect on strategies contributing to the project's success through a "talk story" dialogue between the authors and Cultivando leaders. We offer an innovative, community-centered thematic analysis of relational and research strategies leading to successful project implementation, centering perspectives of Cultivando's leaders. Talk story utilizes dialogue and shared personal narratives to generate meaningful data through a relational process (Beltrán et al., 2024; Steele, 2012) that mirrors mutualistic mycelial systems. Rooted in principles of Indigenous story work (Archibald, 2008)—including mutuality, reciprocal exchange, and deep relational accountability—dialogues center on a particular question or topic, but unfold in casual, conversational processes (Beltrán et al., 2024; Steele, 2012). In this case, we use talk story to engage our partners in a reflective dialogue about the strengths and challenges embedded in our CBPR project. Our thematic analysis of this dialogue highlights the relational processes that enabled successful CBPR implementation, alongside challenges and opportunities for growth.

2 Community-based participatory research: history and challenges

Community-based participatory research (CBPR) emerged in the 1940s in response to limitations of positivist research and hierarchical processes favoring universities and academics over communities. Social scientist Kurt Lewin developed this approach to conduct research with communities affected by systemic oppression and as a tool for social change (Collins et al., 2018; Shalowitz et al., 2009; Wallerstein et al., 2018a). Since the late 1960s, its core principles of equity and meaningful participation of community members, stakeholders, and researchers have evolved into a widely accepted methodological framework across disciplines addressing historical and contemporary health and social inequalities (Shalowitz et al., 2009; Wallerstein et al., 2018a; Israel et al., 2012; Wallerstein et al., 2018b).

CBPR is often challenged by power imbalances between researchers and communities. Traditional research often places academics in positions of authority, which can create tension and mistrust between researchers and impacted communities (Ross et al., 2010). A history of exploitation of disadvantaged communities (e.g., the Tuskegee Syphilis Study) and "helicopter" or "drive by" research—which prioritizes data collection regardless of its community impacts—created justifiable mistrust of

researchers and institutions (Wallerstein et al., 2018b). Ensuring equitable participation and decision-making among those contributing to or being studied and those conducting a study requires ongoing effort to balance these dynamics. Taking time to develop trusting, reciprocal relationships is key. This requires explicit, transparent, iterative discussions about correcting any uneven power dynamics.

Another challenge is the time and resource commitment required for successful CBPR. Building and maintaining genuine partnerships takes considerable time, which can conflict with rigid timelines of academic research funding and publication cycles (Littman et al., 2023; Minkler, 2004). Securing adequate support for research and community involvement can be difficult and lack support. Tensions may also arise between funders’ and communities’ values regarding outcomes and deliverables.

Communication barriers can also pose important challenges. Differences in language, culture, experiences associated with race and ethnicity, and expectations between researchers and community members can cause misunderstandings and misaligned goals (Chávez et al., 2008). Employing effective communication strategies, cultural responsiveness training, and diverse researcher representation can enhance trust and understanding (Chávez et al., 2008).

Research sustainability poses another concern. EJ issues are often long-term, necessitating interventions and remediation over decades (Martin et al., 2020). Ensuring that research benefits continue beyond a project’s lifespan requires careful planning and commitment from all partners (Minkler, 2004; Minkler, 2005). This includes collaboratively developing strategies for sustained community engagement and capacity-building, enabling communities to continue addressing EJ issues independently (Chen et al., 2012).

Chen et al. recommend effective “scholar-practitioner” (Chen et al., 2012) (p. 417) engagement through: 1) adopting a co-created CBPR framework; 2) developing partnerships between researchers and community partners with shared agendas; and 3) researchers serving in collaborative or consultant roles rather than as initiators to “maximize community-generated research, action, and education (Chen et al., 2012, p. 417). Below, we provide context on EJ impacts in our partner community. Then, we detail how our research team enacted these recommendations across project stages, highlighting additional relational strategies to address challenges. We utilize a mutualistic mycelial metaphor there since it aptly illustrates how deliberative we were in using methods and working with an organization that reflect polycentric power dynamics and mutually enriching approaches to data collection and community engagement.

3 80216: the most polluted zip code in the United States

Since the 1940s, residents of Denver’s 80216 zip code have faced layered environmental injustices. This area is exposed to multiple hazards, including pollution from petroleum refining, grain elevators, animal processing facilities, manufacturing, and freight activities along the I-25, I-70, and I-270 corridors. Today, Suncor Energy operates Colorado’s largest (and only) petroleum refinery

TABLE 1 Selected demographics of AIRE study participants.

Geographic	% (n)
Commerce city	58% (31)
Swansea-Elyria	11% (6)
Globeville	9% (5)
Cole	2% (1)
Clayton	2% (1)
Park hill	2% (1)
Outside 3 miles (teachers in sample)	9% (5)
No Response	6% (3)
Race or ethnicity	
White	8% (4)
Hispanic, Latine, or Spanish	60% (32)
Black or African American	9% (5)
American Indian or Alaska Native	2% (1)
Mixed (2 race/ethnicities or more)	15% (8)
No response	6% (3)
Gender	
Female/Woman	74% (39)
Male/Man	15% (8)
Non-binary/Third gender	4% (2)
Prefer not to answer	2% (1)
No response	6% (3)

within this community. In 2017, ATTOM Data Solutions identified 80216 as the most polluted zip code in the United States (Finance, 2017). The predominantly Hispanic/Latine population—comprising 60% of residents (U.S. Census Bureau, 2022)—faces disproportionate exposure to air, water, and soil pollutants (see map 1). Decades of EJ research highlight severe health and social impacts of industrial pollution on these communities (Bullard et al., 2008; Mohai et al., 2009; Taylor, 2014; Roberts et al., 2018).

In 2019, the Suncor Refinery released a hazardous blend of chemicals, including clay-silica dust, which settled on surrounding communities. After decades of violations and ongoing negligence, the Colorado Department of Public Health and Environment (CDPHE) levied a \$9 million fine on Suncor, which was allocated to the Supplemental Environmental Projects (SEP) process in 2020. The SEP initiative solicited proposals in a competitive process for community-driven projects to address the refinery’s impacts.

Cultivando—a trusted local non-profit serving Latine and Indigenous migrant communities in Adams County, Colorado—was approached by community members to propose an air-monitoring project documenting air pollution impacts on neighboring communities. Cultivando’s mission centers on the *promotora* program. Promotoras are trusted community members who activate, advocate, and mobilize impacted communities by providing access to resources, education, and

awareness programs. They also recruit and engage local volunteers. The promotora model is widely recognized as culturally informed for outreach and empowerment and has been adopted by institutions such as the Centers for Disease Control (Madana et al., 2023). Like mycelial networks, promotoras establish deep roots and build extensive networks of connection within impacted communities. They communicate, process, and remediate impacts from the stresses and risks of living near industrial activity. Like mutualistic mycelia, the promotora structure acts as a conduit for holistic collective benefits, accessible communication, and meaningful access to knowledge about the refinery. They facilitated our team's entry into the community, while ensuring our work benefitted residents. In many ways, they enhance spatial dynamics of environmental justice by 'webbing out' into the community, fostering procedural equity in a context of deep inequities between the community and the refinery.

3.1 The air quality investigation and research for equity (AIRE) project: case study

We highlight how our CBPR approach reinforced and enhanced existing community-generated mutual aid networks that mirror mutualistic mycelial networks. The project was uniquely community-based, -led, and -responsive from the pre-proposal stage and remained engaged after the formal research period. At each stage, we collaboratively and systematically documented and analyzed the refinery's air pollution and EJ impacts in community-centered ways, with embedded feedback loops. Over 1.5 years, we conducted participant observation, a photo-narrative project, and in-depth interviews with 53 impacted community members (See Table 1 for selected demographics).

While we have published results from the AIRE research project, including manuscripts detailing the impacted community's experiences with state-facilitated corporate crime through the fossil fuel industry, (Malin et al., 2024), impacts on children's health, (Malin et al., 2025a), and contested illness, (Malin et al., 2025b), in this paper, we focus on reflections from our CBPR process with community partners to illustrate how we implemented an ethical, relational, and mutually beneficial research process. We have also detailed these steps, procedures, and relational processes in a graphic illustrating the non-linear progressive process, feedback loops, and winding mycelial path, which we share below.

3.2 Development/early design: embedded roots

Consistent with Chen et al.'s (2012) recommendations, the community initiated this project (Chen et al., 2012). The authors (PIs) were carefully selected to collaborate because of our relationships with Cultivando, impacted communities, and expertise in EJ research. Our positional identities and reputations for conducting community-centered EJ research and advocacy were key in developing our deeply collaborative relationship. Ramona Beltrán is a multiracial Chicana of Indigenous Mexican descent and, as an Associate Professor of social work, has been working in the area of historical trauma and healing, social and environmental

determinants of health, and storytelling methodologies for almost 20 years. She is a member of the Latine and Indigenous communities and is proficient in Spanish language. The Stephanie Malin is a Professor, environmental sociologist, and advocacy researcher who conducts community-based work investigating the EJ, health, and governance impacts of extractive industries like oil and gas and uranium. She also explores communities with local-level systems of mutual aid, degrowth, and other mechanisms of distributive and regenerative community-building. Her work is highly regarded in EJ advocacy communities and because of this, she has been a trusted research partner in areas where extractivism has had long-term and layered impacts. She was introduced to Cultivando by a local environmental activist who recommended her expertise for the project.

While our positional identities, reputations, and previous relationships helped establish trust, the community drove the project's aims, during a year-long, pre-grant development phase. Cultivando's leadership convened regular meetings to discuss strategies with community partners, impacted residents, and scientific teams. We spent substantial time bearing witness to concerns of impacted community members, which informed goal setting, grant writing, and project implementation. Guided by community-building meetings, we identified our goal: documentation of lived experiences of those working or residing (currently or previously) near the Suncor refinery. We co-designed the project's flow, interview questionnaire, and study elements with community partners.

Project PIs used pre-grant and co-design phases to create non-extractive relationships with the impacted community. Community members and our partner organization consistently led: they called meetings, created agendas, and acted as initial hyphae between community and science teams. Invited into these fertile community spaces, we provided more sustenance, additional points of communication, bi-directional learning, and opportunities to move that mycelial structure towards larger-scale social scientific observations. This approach mirrored mutualistic mycelial networks, fostering 'rootedness' and polycentric power in collaboration with an already 'webbed out', community-centered organization. Our role was to enhance pre-existing linkages and identify where social science hyphae could document community experiences and communicate findings to state agencies and policymakers.

3.3 Co-design: extending threads into community

Community members played central roles in research design and implementation, including co-developing interview questions, and network sampling/recruitment. Prior to IRB submission, we conducted multiple feedback sessions to gather input on the safety and implications of our questionnaire with Cultivando staff, promotoras, and impacted community members. To ensure trauma-informed research practice, we developed a health, mental health, and community support resource page for participants, which was vetted alongside the protocol by our IRB. Research staff were trained to respond to emergent health or mental health issues. To live-test the questionnaire, we held an in-person

practice session with Cultivando promotoras and project leadership. We were able to: 1) introduce new research team members to Cultivando and community; 2) train research assistants to sensitively conduct interviews; and 3) test translations, accessibility, and questions' clarity. We hosted the session at the local community center, which provided transportation ease, and Cultivando provided a meal from a local Latine-owned restaurant. Meeting in a familiar, comfortable space—sharing food and time with multigenerational families—fostered community cohesion. Physical presence invited joyful connection, alongside executing important work in collaboration. During the session, promotoras corrected and enriched our guide, assuring questions connected with community needs. Offering us access to an already well-developed structure (much like mutualistic mycelial systems), promotoras connected Cultivando's programs and our research, adding depth and nuance to what we captured about community members' vital experiences.

3.4 Sharing findings: transferring nutrients to impacted soil

As we analyzed data from the interviews, photo-narratives, and participant observation, we shared preliminary findings, addressed community-wide questions, and ascertained opportunities to refine subsequent interviews. We co-hosted several community meetings with Cultivando to facilitate collective connection, sharing, and feedback loops. One large-scale community meeting accommodated over 100 people, including media, bilingual translation services, the full research team, and members of Cultivando and other community organizations. Cultivando actively co-presented and communicated with attendees. Our team leveled typical power hierarchies by reserving ample time for audience questions and feedback. Like regenerative, mutualistic mycelial networks, we shared information, supported processing, and responded to community needs. We later held two press conferences—in spring 2023 and 2024 at University of Denver. In 2023, the entire research team shared in-depth findings to press, regional political leaders, and organizers. In 2024, we prioritized social science/EJ data, while Cultivando's team shared air-monitoring results accessibly. Acting as hyphae, our team extended networks to communicate important risks created by the refinery and the stories of people most impacted.

Post-data collection, our team hosted an end-of-project celebration. Reflecting the nutrient transfer and reciprocal care of mutualistic mycelial networks, we gathered with Cultivando over a shared meal. We shared finalized findings with promotoras and leadership, highlighting concerns about state-facilitated harms from the facility; (Malin et al., 2024); children's health; (Malin et al., 2025a); mis- and dis-information; pollution; persistent physical and mental health impacts; and lack of oversight and regulation.

This celebration created space to *collectively* process results with community members. Cultivando leaders and promotoras asked questions, discussed next steps, and requested authentic reflexivity from our team. Sharing our motivations for community-based EJ work, strengthened polycentric networks of connection and care. By

connecting as human beings with concerns about wellbeing and health, not as hierarchically situated, distant researchers and “subjects”, we enhanced our approach to power dynamics and community-centered engagement.

3.5 Dissemination and ongoing collaboration and support: nurturing the soil

We continue our commitment to the impacted community through ongoing sharing of analyses and publications. Students from University of Denver Graduate School of Social Work with Cultivando to create bilingual, accessible infographics and powerful campaign information (see Figure 1 for sample infographic).

We've invited Cultivando leaders and EJ staff to review pre-submission manuscripts and maintain ongoing communication regarding data analysis and next steps. We prioritize accessibility by targeting open access journals. We continue collaborating with Cultivando on other projects, webbing out to involve other universities and community organizations.

Our continued collaboration illustrates mycelial parallels: extending, connecting and building interwoven ecosystems of reciprocal communication and learning. These add layers to the robust mutualistic mycelial network created by Cultivando. Our CBPR approach built authentic collaborative relationships, which encouraged less colonized and more procedurally just research, while avoiding extractive, disembodied, or parasitic approaches. Below, we illustrate our progressive, non-linear steps, strategies, and relational processes as templates for implementing CBPR with communities impacted by environmental injustice. See Figure 2 for a visual representation of this process.

4 Findings: talk story dialogue—regenerating to renew the soil

We illustrate how our approach worked so other public health and EJ researchers can use similar strategies with disproportionately impacted communities. To document our talk story, we convened our research team with Cultivando leadership, who are co-authors on this article, via Zoom and shared guiding questions with Olga, Executive Director, and Laura, Manager of EJ Programs, including: 1) What was your experience with the social science research process?; 2) How did you define and direct the process?; 3) What were your expectations of researchers?; and 4) What were any challenges, road bumps, or lessons learned along the way? After cleaning the dialogue transcript, we utilized Dedoose analytical software to conduct an iterative thematic analysis. Ramona and Stephanie began with first-level coding, independently identifying overarching meaning units in the transcripts. Upon completing first-level coding, we met to discuss codes and clarify additional subcodes. Review revealed significant overlap and agreement on codes. We met again to refine codes, discuss our shared understanding of code definitions and descriptions, and organize them into salient themes. Below, we share the emergent themes with corresponding excerpts. We

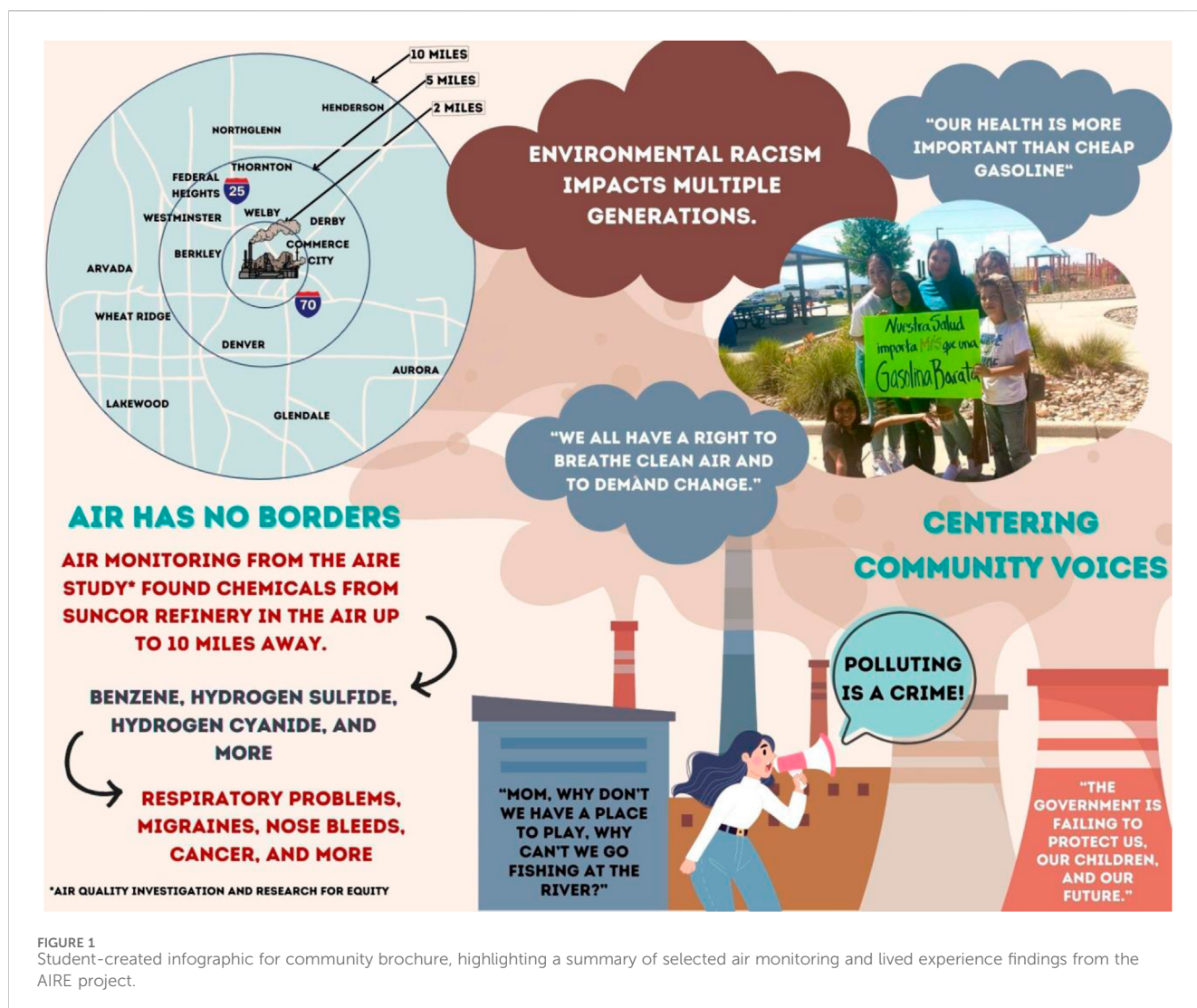


FIGURE 1
Student-created infographic for community brochure, highlighting a summary of selected air monitoring and lived experience findings from the AIRE project.

shared the themes and manuscript outline with community partners for member checking, receiving positive affirmation of accuracy. As a case study of a successful collaborative project, we use talk-story in a reflective, structured process to identify specific processes that facilitated a project built on trust and mutualistic relationships. While not generalizable, this iterative, relational *process* offers important insights and concrete ideas for researchers and institutions to enact CBPR values, ethics, and community-centered objectives.

4.1 Rooted relationships

Aligned with Chen et al. (2012), we foregrounded relationships as central to community engagement (Chen et al., 2012). This reflects the rootedness and polycentric structure of mutualistic mycelial structures (Cantor et al., 2018). Partners emphasized that while the research component felt daunting, our trust-based connections made participation more approachable. Olga stated:

It was important for me from the start to partner with you, [Ramona], because I knew you. Obviously, I got to know you also, [Stephanie], through this work because I was very hesitant about working with scientists, period, because of all the reasons again in the way that we are studied and analyzed. It gets interpreted through the lens of someone from outside of our community. For me, it was important to engage [Ramona] at the time because she was the only scientist I knew. I had a relationship [with her], and I knew that we shared values and space and community. I needed that to know everything was happening in the way we [Cultivando] want to work with community. That made it easier. We had a huge advantage in having that relationship.

Along with strong relationships, our partners described co-design as central to fostering community leadership and ownership over goals, methodological approaches, and outcomes. Co-design also disrupted imbalanced power dynamics, enabling polycentric empowerment to emerge and grow. Laura said "I was happy with the way my team was engaged," in referencing how the

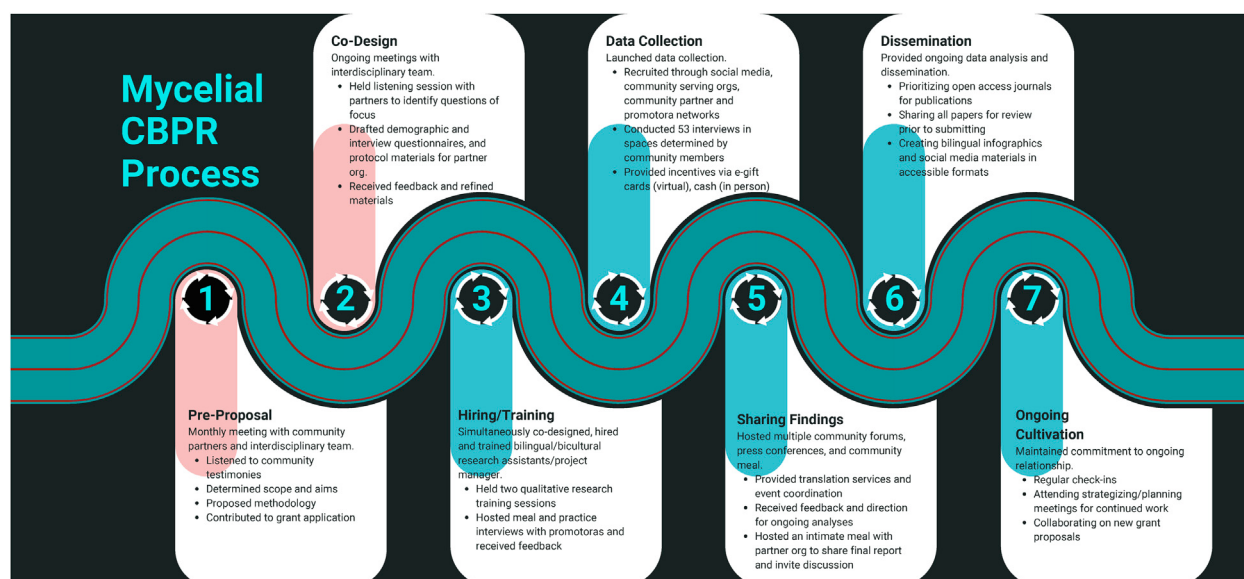


FIGURE 2

Illustration of progressive stages of CBPR process. Rather than linear and hierarchical depiction, here we depict the fluid and collaborative process we co-facilitated from pre-proposal through dissemination and ongoing project development. While the stages are numbered and progressive, the process arrows indicate the ongoing feedback loops embedded through all stages and a winding fluid path similar to mycelial movement.

research team prepared and presented questions with openness and invitation of feedback. She described this as a rare, empowering experience:

There was plenty of opportunity for us to give feedback and say “[What] we really want to ask is this.” Or even to pivot when the questions were not getting at what we really needed. Like “Maybe they were the wrong question? Let’s rephrase this.” There was always that flexibility. I never felt pressure to doing it a certain way. It never felt like a condescending relationship. It felt like we were in partnership. I felt empowered. My team felt empowered by that. There was no agenda other than to work together.

Unlike previous traditional research experiences, we cultivated a transparent partnership with circular processes to align methods with community objectives. This relational accountability emphasized continuous feedback to support a genuinely community-led approach. It also became a training and learning experience for researchers and community-members alike. The trust nurtured continued connections, relational expansion, and polycentric empowerment for the organization and researchers. Laura further explained:

It felt like something I had never experienced, where it was truly community-led. Because we’ve been told that things would be community-led and community would have input, but then that was not the case. Every step of the way—from the envisioning what we wanted to do, to the creation of the questions, to engaging the team, to identifying people in community who would be part of this, to inviting us back to meet in person, to share space, to share a meal, to share the information, to allow us

to give input and to ask questions and to reflect—we learned a lot from that process.

Through co-design and consistent communication, our CBPR approach mirrored a mutualistic mycelial network, fostering reciprocal learning, trust, and reciprocity. We continue to build on this through ongoing projects and expanded research efforts.

4.2 Cultural humility and responsiveness

Communication barriers due to language and cultural differences are common challenges in CBPR. To address this, we worked diligently to ensure that our team was predominantly bilingual/bicultural and grounded in a framework of cultural responsiveness. Alongside Ramona’s shared bicultural identity with the community, we employed bilingual/bicultural graduate research assistants familiar with CBPR and community-engaged research, and a bilingual/bicultural project manager with familial and geographic ties to the community. We understand that language and culture are both nuanced and complex—reflecting experiences of national origin, immigration, mobility, socio-economic status, connections to land, and community as well as experiences of racism connected to phenotype and physical attributes. In team meetings, we reflected on our positional identities, including privileges associated with university affiliation, citizenship, race/ethnicity, socio-economic status, and skin color, and how these influence participant responses. We emphasized transparent communication in interviews and workshopped ways around areas of heightened sensitivity, such as hesitancy discussing Suncor when participants had family

employed there. We emphasized the need to remind participants of voluntary participation including with individual questions. We prioritized developing Spanish and English materials, relying on multiple members of our team in partnership with Cultivando to ensure accurate and accessible translations. Laura explained how much this meant to her: “I love the fact that we had that opportunity to do it in Spanish. Because of that trust, we were able to as a team . . . cooperate in a deeper sense.” Olga affirmed this experience, saying: “The importance of having bilingual researchers. The team that you all assembled or even having some working knowledge of Spanish enough to get by, that was helpful.” She described how she is often charged with the additional labor of providing translation despite her statewide executive director duties, a non-compensated aspect of her job eased by our team’s skills. By valuing partners’ time and resources, our approach strengthened connections, transcended typical hierarchies, and advanced mutually beneficial processes supporting the research, partner organization goals, and community needs.

4.3 Destabilizing power inequities

Beyond language and culture, understanding and destabilizing historical and contemporary power imbalances in university-community relationships was also noted as a key attribute of our team’s process. Olga stated:

Sometimes the positionality of researchers with institutions can seem like, “No, we’re directing this . . . We’ve done tons of this in other places, so we know what works.” You never showed up like that. There was always this openness, this respect and a humility to learn and to say, “Let us know what we are missing or what do you think?” It always felt like we were in an equitable relationship where there was that mutual respect for the expertise that everyone brought to the table. You humanized a process that could otherwise be very dehumanizing, where we could be reduced to numbers and data.

Prioritizing community expertise guided our methods, which focused on gathering community perceptions about life near a refinery through in-depth semi-structured interviews. To accommodate varying comfort levels, we offered flexible options, including virtual interviews with cameras off and in-person interviews in private, community-selected locations such as homes, the library, and community center. While the air-monitoring science provided valuable information about pollutants, the social science component gave that data voice, reflecting stories of people most impacted, which Olga and Laura described as affirming. Specifically, Olga elaborated on the humanizing experience of our social science approach and of research that centers relational approaches:

Everyone was turning to who they thought were experts and that was the air monitoring and the scientists. There was never, look at the people, look at the children that are impacted. Let’s talk to them. It’s ridiculous how in mainstream research, there’s very little value given to people’s actual lived experience in real time.

Beyond the legitimacy given to rigorous research, hearing stories documenting individual and collective health impacts, contested illness, and institutional gaslighting were welcome interventions—a balm for the soul that helped generate polycentric empowerment. Olga continued:

We’re not making this up. We cannot just conjure up asthma and breathing problems. I cannot will myself to have nosebleeds on demand. Yet, we are met by institutions that tell us otherwise. It’s this gaslighting that happens that feels very violent, very heavy, very dehumanizing. What you all did was brought back and elevated those issues that human beings are being impacted [by]. Families, children, communities are being impacted because of the environment in which they’re living in. Humanizing this process was what we needed for our soul. We continue to need that.

Our rapport-building mirrored mutualistic mycelial networks aligned with our community partner’s approaches. These efforts opened previously closed networks, destabilizing power inequities in university-community research by providing access to historically exclusionary spaces and resources. Partners described the positive impact of attending press conferences on the university campus. Laura described how the social science project worked on “incorporating more diversity, how it’s being more inclusive, how community can go and see this beautiful campus and imagine and say, ‘Wow, I get this opportunity too.’” Olga elaborated on the deep impact of being on a college campus for historically excluded communities:

Even the fact that we could then take our community to University of Denver for the press conferences, to share the data, meant a lot, because these are families who never had the privilege of stepping into a university campus. These are families who did not have the opportunities to go to college and who want this for their children. These are families who now can envision, ‘My children can go to college. My children can be on these campuses.’ Being able to be in that space meant a lot to them. Because already we’ve learned that we do not matter, that our existence does not matter. This is what all of this environmental genocide is about, our existence does not matter. To say, “You matter to us, and you belong on this campus” [to say], “You belong in spaces where this data is being shared. Your voice matters. Your experience matters. Your children matter.” To be seen after not having been seen or heard for decades. You are saying, “We’re going to amplify what you’ve been saying. We’re going to create a forum for this with important people. We’re going to broadcast this.”

Our team’s links to our community partner mirrored mutualistic mycelial behaviors, where hyphae break down barriers to create environments that support growth and thriving. Even as mycelium changes those ecosystems, though, they generate sustenance for other beings in the soils they enrich via ‘additive consumption.’ (Tsing, 2015) Beyond providing access to previously exclusive spaces, resources offered through event coordination, planning, and staff support alleviated burdens on Cultivando staff and helped balance power dynamics. Olga described the impact:

We're so used to that at the grassroots level. I walked in tense, what do we have to do? It's like wow, even somatically I could breathe, I could relax, my shoulders dropped. I was like, "Guess what guys? We do not have to set up anything and afterwards we do not have to clean up either." It's these things that in some settings, people take for granted. That's the way it is. To have that all be offered without us having to worry about set up or payment.

In disrupting typical top-down power hierarchies, this CBPR approach nurtured the connections we'd formed, building polycentric trust and comfort beyond data collection.

4.4 Project challenges: impacts of a legacy of trauma

We encountered challenges as partners—largely stemming from systemic injustice and its associated traumas. At one point, our recruitment slowed, and we struggled to find participants. As we reflected on that moment, Olga and Laura described the trauma embedded in communities with complex relationships to powerful industries, not just because of their money and influence but as employers. Laura, who lives near the refinery, described feeling surveilled by the company as a challenge to feeling safe to share, even when data is anonymous:

It's so frustrating wanting to say what you feel and not being able to because you risk your livelihood or being afraid of surveillance or being afraid that your family can negatively be impacted by that. That was one of the major roadblocks that we saw in our community and that I somehow experienced [too].

Laura continued to describe how trauma impacted research recruitment and the organization's challenges with deeply trusting the research process:

Because of that past trauma and those trust issues that the community has had, it was still challenging to get communities to do some parts of the research ... That relationship with Suncor in this case was very difficult for some community members to be able to openly share what they were feeling because their family or their livelihood was somehow connected to this entity. Because of that, they felt threatened or maybe more conservative in sharing.

Although Cultivando is a well-established community-serving organization, historical mistrust within impacted communities underscores the need for sustained, intentional trust-building. The mycelial metaphor is apt: nurturing long-term, mutually beneficial and empowering connections and the health of that soil (trust) is vital for healing traumas of extractive research and industries. Parasitic mycelial networks similarly reflect the unjust power relations inherent in extractive production systems, complicating efforts to foster mutualistic connections and rootedness. As researchers and community advocates, we acknowledge that not all community members could be reached, and survivor bias and fear of reprisal likely influenced participation. Potential participants employed at or

connected to Suncor may have hesitated to speak openly due to concerns about visibility or generational normalization of harm, leading to underrepresentation of more vulnerable voices. While we successfully recruited participants, the narratives captured likely reflect a subset of voices, and future work should explore strategies to reach those excluded. We also understand that silence and refusal - whether rooted in fear of reprisal, economic dependency on refinery employment, or the normalization of harm - constitute powerful sources of data as well.

Despite challenges and barriers, Laura and Olga detailed how hope emanated from our team's exchanges. While we documented difficulties of living near the refinery, we also documented community strengths and possibilities. Framing community data beyond deficits, challenges, and trauma was key within our application of CBPR. While a sense of normalizing the challenges as "just how it is" was present in the empirical data, hope was also embedded in expressions of intergenerational care. In our talk-story dialogue, Olga observed connections to ongoing community empowerment in the face of normalizing harms, as she reflected on our community meal in which we shared initial findings:

I'm thinking of that last meeting in person we had at the university. I remember that there were things about it that I still think about like the component around [normalizing conditions]...the fact that there were some people that had learned nothing changes and had lost hope in systemic change were like, "Well that's the way it is" or "We all rely on gas." That is something that stood out because I realized in our work and in our communications campaign, we had to be about what is possible and not accepting what is.

Beyond documenting lived experiences, CBPR nurtures ongoing relationships that sustain hope and possibility; just as mutualistic mycelial networks transfer nutrients through interconnected roots, long-term relational commitment allows community strengths and empowerment to flourish even amid normalized harms.

4.5 Long-term relational commitment

Like mutualistic mycelial networks, which transfer nutrients through interconnected roots, CBPR projects require long-term commitments. Our team's engagement, grounded in environmental and social justice, has maintained enduring partnerships with the community. Olga emphasized how important this demonstration is to her as a leader and to the organization. She described this ongoing presence as a "gift":

Even this conversation about how do we continue and how can we support you with grants? You [Ramona and Stephanie], elevating this through your research, this is still at the top of your minds. You have not done the thing years ago and moved on to something else. You have not forgotten about us. You continue to be here for the long haul. That, I am sure, is unique because even with the best of intentions and even if we just had done the health impact study, that would have been enough, but it continues. It's like the gift keeps on giving. The relationship continues. That is meaningful because we continue to feel supported.

Cultivando has used social science findings to support ongoing policy advocacy with Colorado legislators. For example, AIRE project data supported testimony during a Rulemaking Hearing (Regulation # 30 5CCR 1001-34), which considered revisions to adopt rules to propose health-based standards for priority toxic air contaminants. Ethical CBPR can foster approaches that mirror mutualistic, polycentric, rooted mycelial networks which require co-nurturing by all participants over time. Researchers hold responsibility for nurturing trust, watering the soil, and ensuring communities and partners perceive continued engagement as valuable for policy and health advocacy.

5 Discussion

Our case study offers rich examples of how our research team enacted CBPR principles. Using mutualistic mycelium as a metaphor for intricate relational processes, we highlighted our grounding in deeply rooted relationships with partners and the impacted community, guided by a commitment to environmental and social justice. We illustrated how slow, iterative relational processes with feedback loops from pre-proposal through dissemination helped us transcend common CBPR barriers. By centering community goals, building a culturally representative team, and offering multiple venues for data sharing, including community meetings, press conferences, and diverse publications (e.g., peer reviewed articles, infographics, social media content), we disrupted typical power hierarchies. This humanistic, care-centered approach diverges from conventional research approaches, but supported successful implementation and trust-building with a historically marginalized and exploited community. It also facilitated spaces for polycentric empowerment, countering the traumas of extractive research and industrial parasitism of extractive industries.

We detailed and illustrated the relational mechanisms our team utilized—including identity and language representation, constant communication, feedback loops and responsiveness, community presence, methodological flexibility, and relational accountability—with the hope of providing other EJ researchers a template for respectful engagement with impacted communities. Rather than a linear, hierarchical approach, we co-created a rooted, nurturing, and ever-expanding network of community, linked by our shared goal of environmental justice. We hope others will do the same. The metaphor of mutualistic mycelial systems offers a framework for researchers and community organizations to envision building similar structures in other spaces, with their own forms of embedded and situational rootedness to place and community.

We believe communities should be represented beyond the struggles of daily life and recognize that EJ is a long-term endeavor. As polluting industries have operated for generations, achieving a healthy environment may also require generational effort. Mycelial networks provide an instructive metaphor for healing amid environmental and spatial injustices, as they remediate landscapes polluted by plastics, oil, and even nuclear contamination. Mycelial systems offer models for thriving despite “capitalist ruin,” (Tsing, 2015) building polycentric structures and connections to place in the process. To note, consumption habits of

many mycelium can be seen as generative or additive; even as they consume aspects of their environments, they “model a sort of generosity: they [make] worlds for others ... through extracellular digestion”, (Tsing, 2015; pg. 137) even as they consume. Beyond methodology analogy, mycelium models the possibility of hope and re-building amid chronic pollution; foregrounding restorative aspects of environmental justice and healing.

By mirroring a mutualistic mycelial model, we can mitigate the traumas of extractive research and avoid ethically flawed CBPR practices. Solely emphasizing research challenges undermines the stamina needed to address environmental injustice. Recognizing and celebrating successes, achievements, and powerful mobilization efforts highlights possibilities and invitations to continue imagining just futures.

Data availability statement

The raw data supporting the conclusions represented in this article belongs to Cultivando. De-identified data may be available upon request, but is subject to Cultivando and community approval.

Ethics statement

The studies involving humans were approved by Colorado State University Institutional Review Board. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article. The talk story component was part of a formal debrief between researchers and partner organization.

Author contributions

RB: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Visualization, Writing – original draft, Writing – review and editing. SM: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Visualization, Writing – original draft, Writing – review and editing. KH: Data curation, Investigation, Writing – review and editing. OG: Writing – review and editing. LM: Writing – review and editing.

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Conflict of interest

Authors OG and LM are employed by Cultivando.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that Generative AI was used in the creation of this manuscript. Generative AI was used to help reduce word count after original manuscript had been written.

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