



Latinx students embodying justice-centered science: Agency through imagining via the performing arts

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Abstract

Children are often denied science education that engages their emotions and multiple identities. This study focused on ways in which embodied arts-based experiences offer opportunities for such engagement in pedagogical efforts associated with justice-centered science. The conceptual framework that informed the study considers the body as a site of learning, embraces social justice in science education and engages with the dialectical relationship between various structures and children's agency, and frames the transdisciplinarity of imagination. The instrumental case study centered on a fifth-grade class of Latinx students in an urban public school, as they grappled with lead contamination and peoples' rights to clean water through an embodied, arts-based pedagogy in their science class. Analysis of video clips, student work, and other artifacts pointed to three findings on how children engaged with justice-centered science learning via arts-based embodied activities. Through perspective-taking in the dramatizing, children engaged with science ideas intertwined with sociopolitical understandings. Through centering emotions that drama afforded, children experienced empathy and



solidarity with others affected by environmental injustices. Through imagined and enacted participation in struggles that the embodiments necessitated, children engaged in actions to resist injustices. These findings suggest that exploring children's arts-based embodied meaning making in science is a robust area of inquiry. Furthermore, the findings compel researchers and practitioners to consider emotions in performing arts, and how they can deepen engagement in, and exploration of, justice-centered science. Recommendations emerged for practitioners poised to explore justice-centered science with children through the arts.

KEY WORDS

agency, drama in science, elementary school, embodied learning, emotions, imagination, justice-centered science, performing arts, science education

1 | INTRODUCTION

It may be where the arts in education find their culmination—among “the silent beautiful blossoms,” where the young ones can stand together, arms linked under the dark birds, imagining what might be, acting upon their vision as they begin working to renew.

Maxine Greene, 2008, p. 20

Increasingly, scholars argue for science education to attend to the development of sociopolitical understandings as inseparable from scientific knowledges and to consider expansive, dignifying, and affirming forms of science learning that foreground the sociopolitical nature of teaching, learning, and science knowledge production (Davis & Schaeffer, 2019; Morales-Doyle, 2017; Philip & Azevedo, 2017; Santos, 2009; Tolbert & Bazzul, 2017). Creating “false distinctions between scientific and social worlds” (Davis & Schaeffer, 2019, p. 367) leads students to experience school science in ways disconnected from who they are and are becoming, and the communities in which they live. While children are too often denied such opportunities in schools, cultivating both a deep knowledge of science and sociopolitical knowledge of environmental justice issues, positions young people as “transformative intellectuals” (Morales-Doyle, 2017, p. 1037) who employ critical perspectives to engage with science and the world and address social justice problems that continue to oppress minoritized communities, such as environmental racism and health disparities. Opportunities to engage in science through critically examining issues of power and privilege around environmental justice issues allows Black, Brown, Indigenous, and Latinx children to thrive in imagining sustainable and just futures (Kayumova & Tippins, 2021).

Moreover, Bell and Desai (2011) argue that the arts are a powerful way to engage with social justice and “that as much as we use our critical faculties to grasp the complex and invidious ways that systems of oppression operate,” the arts allow us to “engage aesthetic and sensory capacities so as to create and experiment with alternative possibilities” (p. 287). Thus, the arts afford young people to engage with environmental justice issues. Specifically, the performing arts, given their capacity to activate whole bodies, multiple identities, emotions,



dramatic play, and imaginings, open pathways for learners to explore, develop, and express sociopolitical knowledge and responsibility, and become aware of, and act against, injustices (Boal, 1979; Freebody & Finneran, 2013; Wright, 2020). Therefore, integrating performing-arts pedagogies in science teaching may help actualize goals toward the development of justice-centered science education, fostering children's imagination, which is necessary for envisioning and working toward a more just world.

In this study, we focused on one class of Latinx fifth graders, taught by the second author Maria Rosario, studying lead contamination of water. The class learned about lead both in the context of the Flint, Michigan water crisis that has been on-going since 2014, as well as elevated lead levels in their own urban city's public school water fountains. In so doing, they engaged with science ideas of how lead gets into drinking water sources and then affects the human body, tied to sociopolitical ideas of how injustices burden low-income communities of color in disproportionate ways. To explore the Flint water crisis at different scales, and without imposing a distinction between science ideas (e.g., scale breaking down inside the pipes) and sociopolitical ideas (e.g., a family sniffing water before cooking with it and later getting involved in a protest), the class employed "embodied performances" (Varelas, Kotler, et al., 2022). These were developed in different groups using a pedagogical process resembling devising theatre (Perry, 2011), in which there is role play from different perspectives, and which may include words, movement, dance, sound and/or music, props and objects, and other modes of communication. The class had been creating embodied performances of the water cycle during the first half of the school year, so they had developed norms for creating small group performances, which had become a routine part of this class.

We draw on the idea that art is "the most effective mode of communication that exists" (Dewey, 2005, p. 298) and has been a powerful catalyst for social change (Boal, 1979; Dewhurst, 2014; Greene, 2000). We also consider arts-based embodied pedagogies—those that position bodies as sites of learning and meaning making rather than those that see bodies as means/tools to ideate—as potentially transformative for Black, Brown, Latinx, and Indigenous children through creating critical spaces to explore sustainable futures through notions of responsibility (Kayumova & Tippins, 2021). Activism and resistance being "central to the social fabric of Latinx communities' livelihoods, identities, and lived practices" (Anderson et al., 2021, p. 209), we were interested in how Latinx children created and imagined more just futures in an expansive science space that valued their multiple identities (e.g., racial, ethnic, gender, linguistic) as resources for science learning.

Thus, we sought to understand the functions of embodied performances to support students' learning, which we consider to be both knowledge and identity construction (Varelas et al., 2012), within justice-centered science. Additionally, we were interested in understanding the children's individual and collective agency as they engaged in devising theatre and associated multimodal activities to act on behalf of peoples' rights to uncontaminated essential resources.

2 | THEORETICAL FRAMING

We drew on scholarship in two domains—arts-based education and social justice science education—to develop the conceptual foundation of this study. We focused on the concepts of role-play, affect and emotions, and of aesthetic engagement, in terms of the unique affordances that embodied arts-based pedagogies can provide within science learning spaces. Furthermore, we also focused on the structure-agency dialectic to situate what it means to center social justice in science education and explore how children, individually and collectively, construct agency through embodied arts-based experiences, pushing against unjust structures. We also examined how critical arts and science pedagogies may foster the development of expansive forms of agency. Moreover, we considered imagination across the arts, sciences, and social justice education, to craft a transdisciplinary perspective of imagination, centering the humanity of people in ecological relationships within the world and engaging students in thinking about the world beyond disciplinary boundaries.



2.1 | The performing body as a site of learning

In science education, the body continues to be conceptualized in limiting ways as a site of knowledge production (Almqvist & Quennerstedt, 2015; Wilcox, 2009) even though children construct deep scientific understandings and positive science identities through involving their whole bodies in making sense of ideas (Champion, 2018; Kotler, 2020; Solomon et al., 2022; Varelas et al., 2010; Varelas, Kotler, et al., 2022). Attention to various ways of knowing has increased over the last century, which is promising, but science education continues to overlook the body due to the previous two millennia of dominance of western thought that has "largely ignored, if not condemned, the body" (Bresler, 2013, p. 8). This creates a pressing need now "to examine what somatic modes of attention ... mean for schooling and curriculum" (p. 7), across all subject areas, but especially in science, where these modes have not been allowed or centered.

Embodiment in science has been increasingly becoming a topic of exploration, theorized differently in different studies. Recently, Kersting et al. (2023) summed up existing literature by examining the role of the body in science education from existing traditions via "three fictitious personas that stand in for the cognitive, social-interactionist, and phenomenological research traditions" (p. 2), which do not include arts-based conceptualizations. In our previous work and continuing here, we embrace performing arts perspectives to explore the affordances of the body in learning science. Specifically, creating embodied performances in science may resemble the process of "devising theatre" (Govan et al., 2007; Perry, 2011), a type of theatre where: (a) the creation process usually happens in groups, collectively, with no set leader such as a writer or director; (b) multiple modes are included—body movements, sounds, words, images, and so forth; and (c) the line between performers and spectators is blurred in that everyone watches each other's performances, participates in their own, and collectively reflects on each performance. Similar to other forms of classroom dramatic play, embodied performances allow role-play in which children, moving their whole bodies and using movements of parts of their body (e.g., gestures), words, sounds, images, and props along with other children, become entities (e.g., water molecules, acid rain, or lead), and collectively develop ideas and make decisions about how to act out processes (e.g., the water cycle or various forms of pollution) based on what they think is happening initially and on the understandings they construct together during the devising process itself, including the reflections with spectators afterwards. This role-play allows children to explore processes at different scales and points of view (Henry, 2000). Acting out processes is a form of collectively "play[ing] with ideas" (Hadzigeorgiou et al., 2012, p. 605), and through planning, rehearsal, performance, and reflecting on performances together with performers and audience members, children come to construct socially mediated and personally meaningful science understandings (Butler, 1989; Hendrix et al., 2012) as well as revise science representations to create collective understandings of science phenomena (Aubusson & Fogwill, 2006; Ødegaard, 2003). Drama is situated within the intersection of (a) the physical and social world as we experience it and (b) the world created through imagination, which Bolton (1984) called "metaxis." This metaxis is useful for science learning as it allows the exploration of abstract science entities and processes as "insiders" of these ideas (Varelas et al., 2010). Moreover, as children become insiders together with others, while spectators experience their performance, opportunities for collective meaning making and understandings are produced for performers and spectators alike.

Champion (2018), referring specifically to the role of dance in science learning, observed that although embodiment is widely considered "a *public* resource for thinking, learning, and joint activity" (Stevens, 2012, p. 338), embodiment research in learning "emphasizes the significance of the body's role in sense-making, however, it does not explicitly address movement as a creative, cultural, expressive, physical representational medium" (Champion, 2018, p. 20). Arts-based embodiment, via movement and dance, drama practices including process drama, story drama, and creative drama (National Coalition for Core Arts Standards, 2014), and the collective, multimodal communication afforded in devising theatre, offers ways to consider children's embodiment not only as useful in sense-making but also as a place where aesthetic, affective, and imaginative possibilities of being in the world emerge and materialize.



The performing arts offer pathways in classrooms for children's whole selves to become engaged with others and ideas, to "feel more, to sense more, to be more consciously in the world" (Greene, 2001, p. 10), which constitute pillars of aesthetic education. Aesthetic educational philosophy, rooted in Dewey's (2005) philosophy of aesthetic experiences, centers people's experience and "heightened vitality ... [and] active and alert commerce with the world" (p. 18). Aesthetic education in schools has historically attended to children's "appreciative, reflective, cultural, participatory engagements with the arts" (Greene, 2001, p. 6), but aesthetic judgment is also integral to science learning (Wickman, 2006). Aesthetic engagement is not exclusive to the arts, but rather is present whenever sensory experience, perceptivity, risk taking, and imagination become centered and encouraged (Uhrmacher, 2009). Although aesthetic dimensions are present in both the sciences and the arts, "something new is created where science and art distinctions can no longer be easily pinpointed" (Hannigan et al., 2022, p. 799), and aesthetic engagement takes new forms when and where science learning comes together with art making.

Embracing an aesthetic education perspective means that the focus is on sharing in the perspectives of others and that "the activities that compose learning ... serve to initiate us into the human community, in its largest and richest sense" (Greene, 1978, p. 3), providing opportunities to embody and empathize with other points of view (Greenwood, 2011). In this way, performing arts practices, such as devising theatre, provide a way to stimulate empathetic perspective-taking both within the classroom and beyond its walls. Thus, if we are interested in transformative learning in science classrooms, then we would do well to consider bringing devising theatre and justice-centered science together to engage with "the more complex problem space that emerges from multiple perspectives" (Calabrese Barton, 2015, p. 450).

Exploring multiple perspectives, both through negotiating with others during the process of devising theatre and exploring different points of view from within the drama, stimulates feelings and emotions. Despite a noticeable "affective turn" taking place in science education and research (Zembylas, 2016), the affective domain is often left out of school science, which tends to focus more exclusively on the cognitive domain (Girod et al., 2003; Kayumova & Tippins, 2016). Yet the process of creating embodied performances invites emotions, "one of the central mediators of our identities, or ways of being in the world" (Maulucci, 2012, p. 125), and values emotions as resources for learning and participation, rather than relegating them to the margins of classroom experiences. Inviting children's whole selves, including emotions, can contribute to contesting the prevailing norms of science education that limit such experiences. Affect plays an important role in science education, with epistemic affect, which involves the "feelings and drives" (Jaber & Hammer, 2016, p. 161) related to doing science, influencing science learning. Through dramatic play, children experience epistemic affect as they take on various perspectives as their own and empathize with harms that other humans and more-than-humans are experiencing that lead to "the desire to understand a puzzling phenomenon" (Jen et al., 2021, p. 161), and to have epistemic motivation to take action. As children take on other perspectives and live through another's experience through the arts, they develop emotionally informed ideas about justice and engage in "critical emotional praxis" (Zembylas & Chubbuck, 2009). In other words, inviting Latinx, Black, Brown, and Indigenous children's affective engagement through embodied arts-based practices that form connections to themselves, others, the environment, and scientific ideas (Alsop, 2011; Butler, 1989; Littledyke, 2008) is a way for school science to engage in "inter-connectedness, ethics, care, relational accountability and respect toward humans and more-than-humans collectives" (Kayumova & Tippins, 2021, p. 825) and facilitate children's development of their own ideas about justice and of their agency to resist injustices.

2.2 | Social justice in science education and the structure-agency dialectic

Science education is increasingly embracing the idea that engaging with social justice science issues (e.g., environmental racism and classism) is needed to deepen equitable pathways to science learning and engagement (Calabrese Barton, 2015). Making explicit connections between environmental and sociopolitical issues prepares



students to make civically minded decisions with the science knowledge they explore (Calabrese Barton, 2015; Dimick, 2012; Varelas, 2018) and to make connections between how both the environment and groups of people are treated stemming from the troubling social paradigm of domination and colonization (Feygina, 2013). Supporting young people in developing *critical science literacy*, the capacity to engage in public discourse about science through questioning experts and bringing their own knowledge to bear on scientific issues (Schusler & Krasny, 2015), positions them to take action to improve inequitable environmental conditions (Morales-Doyle, 2017; Morales-Doyle et al., 2019; Morales-Doyle & Frausto, 2021; Schenkel et al., 2019).

Social justice science education centers the interrogation of various social, linguistic, curricular, and policy structures and the development of students' agency to engage with and confront inequitable and unjust structures (cultural, social, physical, symbolic, linguistic, political) at various levels (i.e., micro, meso, and macro). Thus, the structure-agency dialectic becomes an essential aspect in the conceptualization of education for equity and justice (Varelas, 2018), which foregrounds the idea that "human activity is embedded in structured historicity" (Gutiérrez & Calabrese Barton, 2015, p. 575).

We embrace Kockelman's (2007) conceptions of individual and collective agency as people's thoughts and actions linked with knowledge and power, involving "processes which are multidimensional, graduated, and distributed" (p. 376). Kockelman operationalized agency into two broad categories—representational agency and residential agency—with various subcategories. Focusing on the act of composing texts, Kockelman considered representational agency associated with the knowledge dimension as including the processes of thematizing, characterizing, and reasoning about the world, and residential agency associated with the power dimension as including the processes of controlling, composing, and committing ideas to action. Varelas et al. (2015) and Morales-Doyle et al. (2021) applied Kockelman's conceptions of agency to science education to understand how oppressive or liberating structures shape and are shaped by agency. In the current study, we use this conceptualization of representational and residential agency to understand how devising theatre creates spaces and places for science education that attends to social justice issues. We consider that representational agency, through the processes of thematizing, characterizing, and reasoning, is what happens in devising theatre as children create, spectate, and reflect on performances among performers and spectators. Additionally, through practicing and imagining actions in the metaxis of the drama, the residential agency processes of controlling, composing, and committing ideas to action become embodied.

Both categories of agency, representational and residential, are important in critical science literacy practices that aim to engage young people with justice-centered science pedagogy (Morales-Doyle, 2017). Building on the critical pedagogies of Freire (2001) and Ladson-Billings (1995), Morales-Doyle framed the goals of justice-centered science pedagogy as the development of both deep science knowledge and young peoples' action, stemming from, and contributing to, sociopolitical understandings of environmental justice, among other justice issues. Embracing such a perspective means that young people engage with local knowledges as they work to tackle issues of equity and sustainability in action research projects. Their agency to resist oppressive structures continually develops through praxis, namely through deeply engaging with science, developing sociopolitical knowledge, and addressing injustices through informed action, and, thus, being positioned as "transformative intellectuals" (p. 1037) who interrogate structures that they come to identify as problematic and use their developing knowledge to consider alternatives.

Development of agency is integrally linked with identity construction, namely how people consider themselves and their roles in the various sociocultural practices in which they participate, and how they are considered by others in the worlds in which they live and learn (Stryker & Burke, 2000). An affordance of the arts is that they open up possibilities for children to engage with their multiple identities through creating, analyzing, and reflecting (Wright, 2015) and "see themselves as agents of change as they develop inquiry, analysis, and negotiation skills that are the foundations of social action" (Nelson, 2011, p. 83). Thus, integrating arts and justice centering practices in science education can invite children to bring in what they know and value, and their racial, ethnic, gender, linguistic, and other identities to science as valued dimensions of who they are and are becoming rather than



ignored, devalued, or considered at odds with each other (Varelas, Kotler, et al., 2022). Through dramatizing, children's various identities that are usually not celebrated in science classrooms, may become visible and affect how they develop and express their agency.

Moreover, the arts can center and give voice to a multiplicity of viewpoints that are often overlooked and silenced (Bell & Desai, 2011). Thus, the performing arts which allow children to use their imagination to explore multiple points of view at multiple scales could be important in engaging students in justice-centered science. Art has played an important role in exposing environmental and sociopolitical issues and acting against injustices (Dewhurst, 2014). Moreover, Wright (2020) argued for "supporting young people in producing knowledge by applying their systemic analysis and transformative agency through creating activist art" (p. 33). Embracing such critical arts pedagogy has the potential to provide generative pathways for students to engage with justice-centered science.

2.3 | A transdisciplinary perspective of imagination

To center justice in science education, through embracing arts-based embodiment as a way of developing children's agency, we have to disrupt false distinctions among domains of knowledge and practice, such as the arts, sciences, and social justice. For example, the arts and sciences are often pitted against each other in the structures of schooling and science education—the arts considered as more imaginative and the sciences more rational. However, meaningful science learning takes place when young people invoke rationality and imagination while envisioning being inside science phenomena and processes (Warren et al., 2001), underscoring the "crucial role of imagination in both artistic and scientific creativity" (Hadzigeorgiou et al., 2012, p. 604). Moreover, research on creativity has shown the value of designing opportunities for children to explore problems across disciplinary boundaries in encouraging divergent thinking and problem-solving (Murcia et al., 2022). In terms of pitting science and social justice against each other, Duncan-Andrade (2009) called a "false binary" the argument that rigorous pedagogy and social justice cannot coexist and support each other, which limits one's capacity to imagine new approaches and work toward creating solutions.

To transcend these binaries and separations within the curriculum, we consider the role of imagination from a transdisciplinary perspective (Takeuchi et al., 2020) in order for imagination to become a "boundary layer" or place of "interactions among disciplinary boundaries that create new places of encounters and interactions" (p. 6). Dewey (2005) associated imagination with consciousness by contrasting it with "the narrowing effect of habituation" (p. 280), which is also echoed in Greene's (1978) conception of imagination as "wide-awareness." Imagination is much more than forming mental images. Rather, imagination can be conceptualized as "a humanizing capacity that enables us to act upon and transform our world" (Lake, 2013, p. 2). No conscious action would be possible if not for imagination, which is "the only gateway through which [these] meanings can find their way into a present interaction" (Dewey, 2005, p. 283). Imagination, therefore, is agency, the intersection of representational and residential agency where knowledge and power meet and create possibilities. We, therefore, need to consider how imagination can be cultivated and supported in schools across these different disciplinary areas so that children's agency and humanity become centered.

Greene (2008) was concerned with the curriculum, above all things, as imaginative possibility (Ladson-Billings, 2016) and saw imagination as vital to education.

Imagination is required to disclose a different state of things, to open the windows of consciousness to what might be, what ought to be. Imagination allows for empathy, for a tuning into another's feelings, for new beginnings in transactions with the world. (p. 18)

To center the humanity of children and their agency in classrooms and in the world, we have to employ a "teleological suspension of disciplinarity" (Gordon, 2011) when considering imagination across the sciences, the



arts, and social justice, which could engage students in thinking about the world in more connected ways. A transdisciplinary perspective of imagination implies that the classroom is not a neutral place of learning, but rather, what Philip and Azevedo (2017) referred to as a "site of contestation" (p. 530), where students do not merely reproduce ideas but rather attend to injustices and inequities that need to be resisted by imagining, naming, and acting on transforming realities through science content learning and identity construction (Varelas et al., 2012).

In this study, we asked how embodied performances and other multimodal performances and communication function in justice-centered science education in an elementary school classroom. The focus is on how such performances provide elementary school students with opportunities for engaging with sociopolitical realities and science ideas to imagine possibilities and hope for more just futures.

3 | METHOD

The study stemmed from a multiyear partnership called Science Theatre for Advancing Generative Engagement (Project STAGE), in which school- and university-based educators collaborate to design and understand the affordances and constraints of embodied performances in elementary and middle school science classrooms. The teachers in Project STAGE teach science among other subjects to grades first through sixth (6–12-year-olds) and the university-based educators are researchers at a large, public, research university in the same city focusing on science, language and literacy, and theatre education.

To attend to the research goal, we used an instrumental case study design (Stake, 1995) within the bounded case (Baxter & Jack, 2008) of the fifth grade class of one of the Project STAGE collaborating teachers, Rosario (the second author), employing arts-based embodied and justice-centered pedagogies to explore the Flint water crisis and the lead contamination in their own city schools. The focus of this study was to illuminate the phenomenon of engaging in arts-based, embodied explorations of justice-centered science learning within this particular classroom. Thus, an instrumental case study design was used to explore this phenomenon in context rather than the context itself being the focus of the study (Kekeya, 2021). To gain insight about the phenomenon, Rosario's class was appropriate because Rosario had pedagogical commitments that center the interaction between arts-based and justice-centered approaches. The students and their sociohistorical positionings as Latinx elementary students, and the school context in a northern US city that is segregated for the most part along socioeconomic and ethno-racial heritages, are also important for contextualizing the findings.

3.1 | Participants

I (Rosario) identify as an Afro Caribbean female of Puerto Rican descent, and Spanish is my native language. I have been teaching fourth and fifth grades at the same public school in a large northern US city (similar to all Project STAGE classrooms) for a decade. I joined up with Project STAGE because of prior productive collaborations with some of the researchers and because of my desire to explore science through the arts and to make science a focus in my classroom. I decided that my personal commitment to using science to understand social justice issues should be reflected in my teaching. This commitment began a few years prior, when I was able to bring science and community issues together into my teaching. I then traveled to Puerto Rico to visit family and one of my uncles there expressed grave concern for the fair distribution of water. The conversations that I had with him ignited a passion for the study of water and its intertwining with issues of justice and from that point forward, I made a commitment to study water with each of my future classes. Thus, as part of my work in the Project STAGE partnership, I designed a year-long integrated science curriculum to study ideas related to water with my students and explore them using multimodal approaches including embodied performances. In my teaching, I also embrace translanguaging practices, "activating [emergent bilingual students'] full semiotic repertoires" (Suárez, 2020, p. 3),



and position all children as knowledge producers, researchers, questioners, audience members, and performers. I frequently invite them to discuss and show their thinking, explain, and question each other, and in this way engage in dialogical power sharing.

Rebecca Kotler (Author 1), a White female and former elementary teacher and researcher at the university, became a member of our class community that year, supporting my efforts and engaging with the children in similar ways. Our collaboration and ongoing partnership in thinking about the integrated water curriculum and the children's learning led to a productive rapport between Rebecca and my students. The other authors are Project STAGE members and university educators and researchers with varying levels of privilege, minoritization, and power, all sharing a demonstrated commitment to pursuing research in science, literacy, or theatre education in collaboration with practitioners that centers the thinking, learning, and embodying of minoritized children in public school systems and out-of-school learning environments.

Nearly all students at this public magnet school offering special programming in math and science and located in a predominantly Latinx working class neighborhood on the west side of the city, are Latinx (96%), with most of the student families experiencing economic insecurity determined by eligibility for reduced or free school lunches (92%). In the year of the study, there were 30 students in this self-contained fifth grade class of which approximately 70% were fluent bilingual Spanish-English speakers and readers and 30% were emerging bilinguals. Approximately 90% of the students were second-generation Mexican Americans and 5% first-generation Ecuadorians. In addition, two children in the class had recently arrived in the United States, one during the school year of this study, and one a few years prior.

3.2 | Context

3.2.1 | The curriculum: Justice-centered and arts-based embodied science

Rosario and the other school-university partners in Project STAGE designed the water curriculum that year. During the first half of the school year, the water curriculum was integrated into reading, writing, math, social studies, and science, and the class explored through embodied performances as well as other modes, the properties of water, the water cycle, and water collection processes, such as groundwater and aquifers. The yearlong curriculum is detailed in Kotler (2020).

During the second half of the school year, which is the focus of this study, the class engaged in learning about issues of water pollution, specifically related to lead contamination, and the sociopolitical realities that influence access to lead-free water. The class focused on the Flint water crisis, but also other drinking water pollution struggles in cities like Detroit, Washington, D.C., and the city where they live. Rosario was guided by her own and her students' developing understandings of water, including filtration, contaminants and their impact on human body systems, and clean water availability and consumption.

During a "fishbowl" discussion, in which an inner circle of students discusses ideas while an outer circle observes, students leveraged their simultaneous exploration of a FOSS (Full Option Science System) unit on human body systems in a discussion that centered on the sociopolitical underpinnings of the water pollution crisis in Flint. Some students expressed their "moral outrage" (Duncan-Andrade, 2009, p. 181) as they collectively addressed the articles and films about Flint, such as *Poisoned Water* (a Nova film), which they had been reading about and viewing.

During the study, arts-based embodiment and other forms of multimodality (e.g., dramatizing, gesturing, building 3-D models, drawing, and diagraming) were enacted whenever possible, upholding an important goal of the school-university partnership. By weaving arts-based embodied practices, while enacting principles of multimodal communication—that different modes of communication have different epistemological affordances (Bezemer & Kress, 2015), and no one mode (i.e., speech or writing) is sufficient (Kress, 2009)—into the justice-centered curriculum, students were asked to not only engage with science ideas verbally but also use their hands or their



whole bodies to represent them, both spontaneously and in planned ways such as in group embodied performances. Embodied performances were worked on for approximately a week, with groups of six to eight students planning and composing enactments of different perspectives of the Flint water crisis that they determined. The groups rehearsed and then performed these for the rest of the class to watch and discuss.

3.2.2 | Being an audience for a social justice science play

In late Spring of that year, the class traveled to the university where Project STAGE was coordinated to be in the audience of different Project STAGE classes from another elementary school, all sixth graders (11- and 12-year-olds), who had created an original full-length play about pollution, exploring with a critical lens how humanity's current air, water, and land polluting behaviors would have a disproportionate effect on future societies, just as they do today. The play included several embodiments of science processes, such as the release of toxic chemicals from factories, enacted by performers dancing as toxins, an enactment of the lead contamination in Flint, and an enactment at the microscopic level of lungs being attacked by pollutants. The play was written and performed to bring awareness to the outsized proportion of pollution for which the US is responsible, the build-up of plastics in ocean gyres, and the causes and effects of the Flint water crisis (which these sixth graders, like the fifth graders in the study, had studied in depth). The production used several modes including large projected images, thematic music throughout, dance, and dramatic scenes. The play concluded with agentic stances in the struggle for a cleaner planet expressed during a question-and-answer portion of the play in which several actors would ask, "why should we care?" and others would give compelling reasons that pollution is causing climate change and what we can do to demand more pollution regulations.

3.2.3 | Action research project involving embodiment

Rosario's class also participated in a different local university's 123 Action Project (pseudonym), a city-wide, annual social justice action project in which this class participated and gave a presentation. Focusing on the dangers of lead, the class was analyzing for a while the publicly available official report by the local school district, which Rosario shared with them, that contained lead concentration measurements in water samples collected from multiple water fountains in district schools built before 1986. Some of these measurements were either at the borderline or much higher than the 15 ppb action level established by the US Environmental Protection Agency (EPA). In their own school, they found in the report that the water fountains and, even more so, those nearest to the youngest children's classrooms had elevated levels of lead.

This report helped the students connect the Flint water crisis to problems their own city and school district were facing. They decided that the action project they would present would have different components: (a) an embodied performance for kindergarteners, (b) a letter writing campaign to city and state officials, and (c) a lead awareness campaign for parents. The embodied performance they planned to do for the youngest children at their school would be about lead and its impact on the human body. Additionally, the students each would write letters to their city's mayor, superintendent of the public schools, and their state governor to inform them of the problems with lead levels they had learned about in the report, and to ask for the schools to install the Coda system (more details provided in Section 4) in the buildings with high lead levels and to provide reusable water bottles to children at schools with high lead levels. Finally, the information campaign for parents would raise awareness of free lead testing kits available from the city. The students also decided to include information about filtering devices that could be purchased, such as ZeroWater™ pitchers, in case any adults were not comfortable asking the city for free kits. The class presented their project to a panel of lawyers, law students, and a member of the city council, in addition to a peer audience from a



different school. To present their project, the students created a slide deck that included videoclips and elaborations on their arts-based embodied classroom science learning.

3.3 | Data collection and analysis

Data consisted of (1) video recordings; (2) fieldnotes on class activities; (3) conversations with students; (4) student class work; (5) conversations with Rosario; and (6) thick descriptions of class work. During the second half of the school year, 12 science classes were visited by Kotler who did the data collection, including video-recording using one camera to capture whole-class and small groups, and jotting down field notes that were expanded upon shortly after the class sessions. In addition, Kotler saw the sixth graders' play with the study class and also watched the class as they presented their 123 Action Project at another university. Kotler had conversations with students and Rosario to capture their thought processes while engaged in activities during each of the visits. Out of the 12 lessons, 6 distinct but interconnected activities took place that were analyzed. These activities were identified as relevant because they either informed and were informed by arts-based embodied activities or they were themselves arts-based embodied activities—see Table 1. Related thick descriptions that were written for a larger study (Kotler, 2020) were also reanalyzed and memos were written in light of the present study's research question.

Within the bounds of this study, namely, the second half of the school year, the students' knowledge and identity construction manifestations, while either directly participating in or reflecting on embodied performances and other multimodal learning experiences, were analyzed to answer the question of how students took part in, and made sense of, arts-based embodied experiences specifically in justice-centered science. This analysis was informed by the themes that had emerged from the larger study of all embodied performances across the academic year (Kotler, 2020). Additional passes through the second-half-of-the-year data were focused on identifying intersections of justice-centered science with embodied performances—the focus of the present study (Heaton, 2004). These passes through the data expanded prior analyses to address the new question (Thome, 1998) focusing on how the arts-based embodied activities were functioning particularly within the justice-centered part of the water curriculum. Whereas previous analyses examined affordances of embodied performances in general, more targeted analysis was needed to uncover how embodied performances were functioning as part of justice-centered science.

TABLE 1 Activities and selection rationales.

Activity	Selection rationale
Fishbowl discussion on the Flint water crisis	The ideas discussed and the emotions expressed within the fishbowl got further developed the following week when students created group embodied performances related to the Flint crisis
Dramatic enactments of the Flint crisis that followed the fishbowl discussion	These were arts-based embodiments
Student reflections on the sixth grade play about pollution that their class attended	These provided data on the experience of being audience to others' arts-based embodiments
Class analysis of the local lead issues using the school district lead report	It informed the embodied performance about lead contamination the class was planning to enact for the kindergartners
Letter writing campaign to city and state leaders	It provided multimodal data on students' ideational and affective meaning making regarding the Flint crisis
The 123 Action Project	It was itself embodied and multimodal and contained students' meanings of the affordances of embodied performances for their learning



We layered interpretations of the six activities using constant comparative methods (Strauss & Corbin, 1998), toggling between video footage, student work such as their embodied performances, the 123 Action Project, written reflections on the sixth graders' play, letters the children wrote to city officials, Kotler's writings in the form of thick descriptions (Geertz, 2003; Ponterotto, 2006) of the activities, and conversations among the authors about these data. This process resulted in codes that were applied to the data, including: *inside perspective, whole-body movement, aesthetic engagement, representational agency, residential agency, translanguaging, emotions showing up, expressed concern for those affected, moral outrage, constructing meaning, expressing solidarity, imagining solutions, transformative intellectuals*. Table 2 shows a sample of codes, descriptions, and examples. As often happens with multiple data sources, some codes applied across different data sources and other codes were specific to a particular data source.

TABLE 2 A sample of codes, descriptors, and examples.

Code	Descriptor	Example
Representational agency	When children reasoned about the injustice, that what happened in Flint was not right	"All the scientists know that the chemical that protects from lead, [if not there] the lead is gonna go off."
Inside perspective	When children communicated a "view" of the idea from within the process itself	"so the chlorine should go first before us. Doesn't the chlorine go, or should we go at the same time?"
Moral outrage	When children expressed disbelief and/or anger at perpetrators of injustice	"Why did they, didn't they communicate with this ... they lied? They lied?"
Aesthetic engagement	When groups showed characteristics of heightened and embodied engagement in planning enactments and generative meaning making in groups	Growing excitement expressed while several group members, Oliver, Ethan, Leo, were talking at once, on their feet and gesturing, trying to convince others of their idea.
Whole-body movement	When performers put their whole bodies in their movements, merging the weight and intention of their gestures with their whole bodies (called posture-gesture merger in Laban/Bartenieff Movement System)	Leo as he goes "voom," army crawling with intensity and speed, sliding his legs behind him in fluid motion, representing water rushing in through the pipe from the Flint River.
Expressing concern for those affected	When children attempted to relate to and/or understand feelings of those affected by lead contamination	"So imagine yourself having lead in your body. How would you feel? How do you think you would feel?"
Solidarity	When students voiced or moved in ways that demonstrated their feelings of togetherness and standing with those who struggle in Flint and in their own communities	Posters were made in Group C, inscribed with: "The water is poisoned in Flint houses" and "We are poisoned and tired of drinking LEAD."
Transformative intellectuals	When students expressed in various ways that science knowledge and the struggle for environmental justice are connected	(in writing) "donde me senti que era científica fue cuando estudiámos sobre el agua contaminada y el plomo en el cuerpo humano." "Where I felt I was scientific was when we studied about contaminated water and lead in the human body."



To code children's body movements, we used a method common in performing arts research and practice, the Laban/Bartenieff Movement System (LBMS) (Fernandes, 2014; Studd & Cox, 2019; Tsachor & Shafir, 2017, 2019). This analytical system brings attention to embodiments along four different dimensions: Body, Effort, Space, and Shape (Table 3), which helped bring out the varied aspects of movement, shedding light on the connections between movements and ideas and identities expressed. Body refers to what parts of the body are engaged in the movement and what the movement action is, such as jumping, swinging arms, rolling, and so forth. Effort characterizes how the body is moving, such as whether it is a light and airy movement or a strong or sudden movement. Space describes where the body is moving, such as along a fixed path or meandering. Shape deals with the changes in movement or Shape changes, such as from a wide shape with arms outstretched to a narrow shape as arms lower to each side. LBMS was useful in analyzing embodied activities, in general, but also in analyzing moments in which movement was not the foregrounded mode of communication, such as during the fishbowl discussion. Consistent with our epistemological commitment to embodiment, LBMS helped us notice, for instance, attentional shifts and helped us tune into emotions through children's body movements (Tsachor & Shafir, 2017, 2019). Using LBMS helped bring specificity to movements as well as connected movements to ideas and feelings, illuminating children's science knowledge and identity construction.

Theory-led and new synthetic categories (Goodrick & Rogers, 2010) emerged from combining and recombining codes during second cycle coding (Saldaña & Omasta, 2016). The three categories, which emerged from this iterative process that combined theoretical insights and abstraction of data particulars to build meanings (Saldaña & Omasta, 2016), were the following: *perspective taking*, *empathy and solidarity*, and *agency*. These three categories constitute the themes presented in Section 4 below.

TABLE 3 Laban Bartenieff Movement System (LBMS) dimensions of movement, descriptors, and examples.

LBMS dimension of movement	Descriptor	Example
Body	Describes what parts of the body are moving and the movement sequence or patterns	Oliver, with both hands, gripped the student's shoulders and then slapped the student on the back several times to be convincing that the plan would work
Effort	Characterizes the quality of the attention in space, activation of weight as force, changes in attitude toward time, or flow of the movement, whether the movement is direct/indirect, strong/light, sudden/sustained, bound/free	To represent pipes, Javier and Braylon extend and straighten their arms with sustained, bound effort, parallel to the ground
Space	Describes where the movement goes through the space in terms of direction, level, size, pathway, and reach-space: Are they reaching out into space with large, extensions, moving in the nearest small space? What is the geometry of the different movements in the space?	Mia, Leía, and Sandy join their fingertips together, extending their kinesphere by reaching fingers together and high up, but stretching as far back with the rest of their bodies so the others can flow through the "pipe" they were creating
Shape	Characterizes the changes in the body's shape in relationship to self, other, and environment: Describes how movements flow within the body, are directional to bridge to the environment, or sink, spread, rise, advance, retreat, and so forth.	The performers playing the family members come into a directional, inward huddle, with little space between them, and sniff the bottle of water. They recoil with a look of disgust by spreading apart, backing away from the smelly water



The trustworthiness measures we took included the “prolonged or intense exposure to the phenomenon under study within its context” (Baxter & Jack, 2008, p. 556) and triangulation of data whenever possible. Rosario and Kotler had built rapport with students through listening carefully to their ideas and allowing them the time it takes to do creative and meaningful work in groups. During conversations among the co-authors, interpretations were questioned, alternative interpretations were explored, and multiple data sources were considered. Viewing video clips during the post-data collection years and having conversations together, helped refine interpretations of the students' engagement with ideas, with each other, with Rosario, and with the world.

4 | FINDINGS

We identified three functions of arts-based embodiments that allowed children to engage with justice-centered science: (a) through perspective-taking children engaged with science ideas intertwined with sociopolitical understandings; (b) through centering emotions, children experienced empathy and solidarity with others affected by environmental injustices; and (c) through imagined and enacted participation in struggles that the embodiments afforded, children engaged in actions to resist injustices.

4.1 | Perspective taking via embodying supported critical science literacy

Dramatic performances about who was responsible (and how) for the Flint water crisis deepened children's levels of engagement with the science ideas, and allowed them to dig deep into the perspectives of various entities and people. The class brainstormed the various perspectives involved that could be represented via dramatic enactments and each group chose a different one to explore and perform for the rest of the class. One group's (Group A's) performance dealt with the physical process of lead leaching into the water within the Flint pipes. Another group's (Group B's) performance dealt with a social process of nonelected officials with particular motivations and power deciding Flint's drinking water source. Across the different foci of these two performances, student/performers questioned, proposed ideas, created movements, and expressed motivations from a view *inside* the process. This perspective taking via arts-based embodiment further supported their development of critical science literacy by creating the need to figure out what was really going on within these processes to dramatize them, and to understand the Flint water crisis from both the perspective of performer and audience, therefore grappling with the crisis from multiple viewpoints and multiple scales, ranging from microscopic, to macroscopic, to sociopolitical.

4.1.1 | From inside the Flint pipes: Engaging with science ideas through embodying lead

Although a film the class had watched, the *Nova* special *Poisoned Water*, led to a class discussion about the city managers' responsibility for the water crisis, it was Group A's dramatic performance several days after the discussion that offered the children opportunities to dig into the scientific process of leaching lead of which the city managers in Flint should have been properly advised had their priorities been more aligned with the people's welfare. After viewing the film and reading several articles, students had a fishbowl discussion, a discursive structure in which first the inner circle of students had a discussion drawing heavily on multimodal texts they had engaged with (i.e., the *Nova* film, various print articles) while the outer circle listened, and then the two circles switched roles. Students responded to each other without the teacher's mediation unless it was needed. At one moment in the fishbowl, Ethan refuted Oliver's point that the city managers may not have known of the dangerous lead levels in the pipes, arguing that they had to know about the corrosion control which “they had to put it in the



pipes cuz then all the scientists know that the chemical that protects from lead [if not there], the lead is gonna go off." Ethan was not giving officials a pass because anyone in their position should know, or be advised by those who know, the science ideas involved. For Ethan, not having this knowledge should not be an acceptable excuse.

While students worked in small groups around the classroom to dramatize different perspectives of the Flint water crisis through embodied performances (Table 4), Group A used their imagination to travel into the underground pipes to figure out what caused the lead to leach and perform this process for their classmates. During their brainstorming session, Group A imagined all of the entities they would need to embody in their performance—water, pipes, the protective layer, chlorine, and lead—but they had not yet figured out a way to do this to their satisfaction and some frustration was noted in Leía's slouching and downcast look while the others were trying to make some progress with a plan. An idea of using various colors of construction paper in their enactment brought some vitality to their interactions, and they began negotiating how the paper could be helpful in representing the lead, chlorine, and the protective coating, and could help the audience follow what was happening.

To represent water flowing through a pipe with their bodies, they decided that Mia, Leía, and Sandy would join their fingertips together at the top of their reach space while creating an area under their arms large enough for the others to represent the liquids that were flowing through. The group decided that Alan and Liam would represent water by wiggling large blue sheets of paper as they walked through the tall, curved formation the others were creating with their bodies. Another student would play the role of the chlorine, also walking through the pipes to show that too much chlorine was added to the water. In negotiating how to make progress with their plan, they decided to rip up pieces of brown paper that Mia, Leía, and Sandy could drop from their hands to represent the protective layer getting damaged as the water and chlorine actors passed through the pipe. This gave rise to the idea of taping pieces of ripped black paper to the back of the blue paper that the water actors would flip once the pipe actors sprinkled the brown pieces of paper.

The group members, showing excitement and commitment to their ideas, began a flurry of ripping and taping bits of paper onto large pieces of blue paper. They were at a point in their process where their various pauses, starts, frustrations, and negotiations gave way to forms of active engagement that could be observed through more focused attention to getting their props and costumes ready. The student representing chlorine was busy taping many pieces of white paper to his clothes to make his costume. Leía, emerging as a strong leader of the group, noticed the pieces all over him and said, "Poor him. That's too many!" as the student, smiling, continued to stick them on his clothes and skin. "No more, not on the face!" Leía insisted, expressing her leadership that the drama process was affording. After several minutes of emotionally charged planning, ripping, taping, and rehearsing, there

TABLE 4 Groups, group members, perspectives dramatized, and multimodal resources in Flint embodied performances.

Group	Group members	Perspective dramatized	Multimodal resources
A	Sandy, Mia, Alan, Leía, Liam, and another student	Inside the pipes	Whole-body movements to represent the pipe and water flowing through it, construction paper in different colors representing water, lead, protective coating, and chlorine
B	Ethan, Braylon, Oliver, Javier, Leo, and another student	Inside the government office	Dialogue between city managers, whole-body movements of characters and water source switching, costume pieces and props
C	Lola, Dante, David, Jessica, and another student	Family (cooking then protesting)	Dialogue between family members, whole-body movements of characters, enactment of protest, protest signs group members constructed



was a sense of urgency and excitement and of aesthetic engagement, while rehearsing the movements as the time neared to present their work.

It was when the group was making last minute decisions to get their performance ready, that taking on the perspectives of the various entities in the pipes and walking through the process allowed them to further interrogate and build their understandings. As Alan walked through the pipe in the role of the water, he tried several times, but his groupmates kept correcting his timing of flipping the paper to the side with bits of black paper, what the students called "the dirty side." Leía assertively directed Alan to wait for the brown pieces to fall and only then flip the blue paper from the clean side to the "dirty side," to show that it was the breakdown of the protective layer that allowed the lead entry into the water (Figure 1). The timing of Alan's paper flipping was crucial to their understandings of what was causing the lead contamination. But the process was further interrogated by the group when Alan then asked them to consider the order that the two water actors and the chlorine actor should walk through the pipe. Walking through the curved formation, as water flowing through a pipe, he realized a disconnect between their bodies and their ideas—that the chlorine would be *mixed* in the water, not separate. He asked how they could represent this with their bodies: "So the chlorine should go first before us, doesn't the chlorine go, or should we go at the same time?" They would have to make decisions about the order because the "pipe" was only large enough to pass through one at a time.

The temporal and spatial constraints of the embodiment, having to move in a particular order in a limited amount of space, led to reasoning together about what order of events would make the most sense based on the process they were coming to understand. Furthermore, coming up with an order for the genuine reason of having to create a compelling and accurate performance necessitated interrogating each step and why it should or should not proceed another or how to represent the order if more than one thing was happening at the same time. Liam thought the chlorine should go first because "he's [the chlorine] going to damage the pipes and then the lead is gonna go into the water," revealing his thinking about what caused the lead to leach. Sandy disagreed and suggested rather that "water and chlorine can go together" even within the limited space, perhaps because this would show that they were mixed together and "it's destroying the pipes and the water." Having to flow through the pipes with their own bodies and material props that carried meaning, necessitated representational agency to develop through an extended interrogation of the process. The productive struggle about which order the chlorine and water should pass through the pipe, and the timing of flipping the paper, was enabled by taking on the perspectives of these entities as the children acted out the process, both bringing up important process questions and further solidifying their understandings of the science involved in lead contamination. Therefore, the embodiment itself, and the perspective taking it enabled, which the impending performance gave urgency, helped strengthen their science understandings.

4.1.2 | From inside the officials' office: Naming and reasoning about injustice

Representational agency that emerged during the fishbowl discussion among Enzo, Ethan, Alan, and David was further developed within Group B, as they were creating a dramatic performance of the city managers arguing to switch the city's drinking water source. During the fishbowl, Enzo asked the question to his classmates: "Why did the government make this bad choice for the first time, switching the water?" Ethan, being particularly vocal and confident in his assessment of the injustice, explained that the choice was reckless and endangering considering it did not reflect the scientific knowledge that should have been available to the city managers. "The place where they cleaned the water wasn't used for 50 years and they didn't put the corrosion control," Ethan further explained, and then argued that the government "lied about the water being safe." David, at first was incredulous asking, "Why did they, didn't they communicate with this ... They lied? They lied?" but Alan reminded them that in the film they had watched, the government "just wanted the money." The speakers' affective responses became more and more intensified, as seen and felt through their increased pace and more forceful expressiveness in their faces, and the

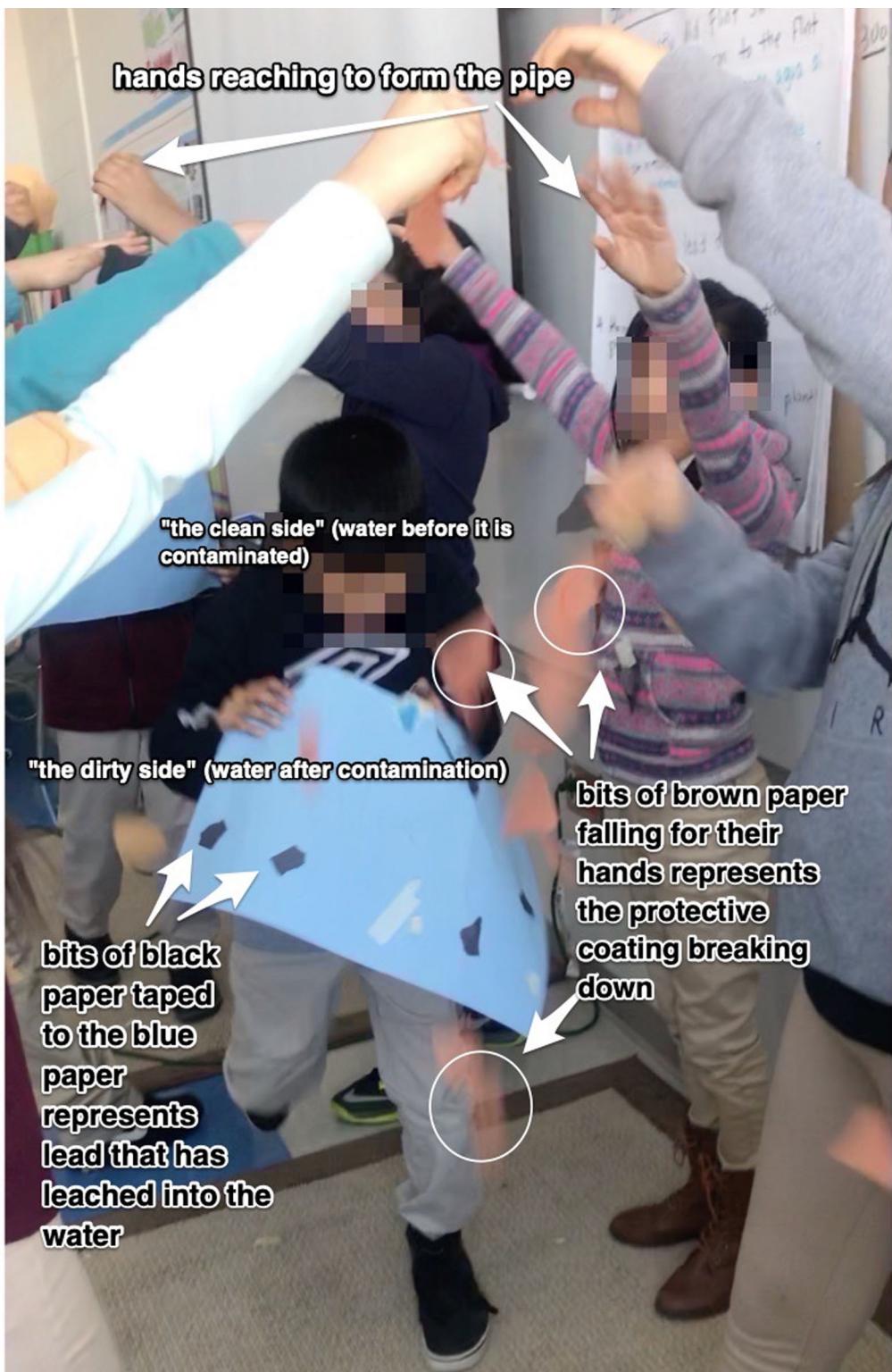


FIGURE 1 Lead contamination of the water in pipes.



listeners focused more quiet attention on what was being said and their body positions shifted a bit more forward in their chairs.

A week later, while Group A was exploring the perspective from inside the pipes, as the previous example detailed, Group B was taking on the roles of city managers who were deciding to switch Flint's water source from Lake Huron to the Flint River. There was tangible energy and engagement as they planned how some group members would embody the water source changing as others would dramatize the decision to switch the water source. Braylon asked, "who's gonna be the pipes?" Javier, volunteering for the role, extended his arms in opposite directions with strong effort, parallel to the ground. Leo, seeing what Javier was creating with his body, suggested for him to "block the part where the Lake Huron water comes," and Oliver added "you're gonna be like this," showing him how to rotate with his arms out to either side to demonstrate the idea that the pipe from Lake Huron was now closed. Leo, offering his sense making, offered: "when they switch [the water source], you close, and this man [Braylon] opens, and I'll go voom," sliding quickly while holding his arms in tightly at his chest and scooching with his legs across the floor enacting the water rushing in through the pipe from the Flint River (Figure 2). Oliver agreed, pointing out that Braylon, representing the Flint River pipe, had to be closed when Javier was in the open position, so they had to pay attention to the sequence and coordination of their movements. Braylon, following the ideas with sustained attention, told Javier, while making the extended shape that the group was coming to agreement on "then we'll switch."

The collective development of ideas on how to embody the mechanical process of closing one pipe and opening another was strengthened by their being in role, inside the process itself, which pushed them to think through how to show it, further generating understanding of the process. Right when the managers pressed a button (that they have constructed and stuck to the wall), this would trigger the switch of the water source represented with the outstretched shape they were making with their arms in either direction, and rotating their bodies to indicate the closing of one pipe and the opening of the other.

The emotional intensity was building, shown by the group's pacing, light jumping and gesturing while trying to add their ideas, as the children became more invested in their roles, moving their whole bodies with the effort that would support their role. As they planned, the excitement continued to mount to the point where several group members were talking at once, on their feet and gesturing, trying to convince others of their idea.

The group rehearsed their part, and Oliver said in an overly confident tone, "We are going to get millions of dollars if we switch to the river!" to which Ethan, who taped dollar signs over his eyes that he had cut out of construction paper, responded, "Yeah, because Lake Huron is so expensive bro. It's gonna cost millions of dollars and switching to the river is cheaper [smiling]" (Figure 3). When a student in the group expressed concern for the people of Flint, Ethan's response to tell him not to worry, and Oliver added with an insincere tone of voice that they were going to put "lots of cleaning stuff in it." As they rejoiced that they were "gonna have millions," fully invested in the roles they were portraying, Oliver hugged the student who had expressed concern, with his two hands gripping the student's shoulders and then slapped the student on the back three times, offering hollow reassurance.

As the children got more invested in the perspectives they were trying on, the perspective of greedy officials who cared only about money, it was clear they were portraying emotions they assumed these officials would be expressing to one another at the thought of spending less money on providing drinking water to Flint residents. As performers, they were interpreting these emotions based on the film they had seen and the articles they had read that revealed the motivations of the city leaders in making this fateful decision of switching the water source. The fact that they were visibly enjoying expressing these thoughts and feelings, with sarcasm and insincerity in their voices and embodied expressions as they assuaged the moral dilemma raised by the actor who was showing concern, was a manifestation of their developing sociopolitical understanding and sense of the injustice. The commitment to the roles they were embodying was clear from their wide smiles, loud proclamations about securing money, their energetic movements (jumping, gesturing, hugging, slapping on the back) portrayed their thinking about how those in power wronged the people of Flint. Through the performers' commitments to the roles and to

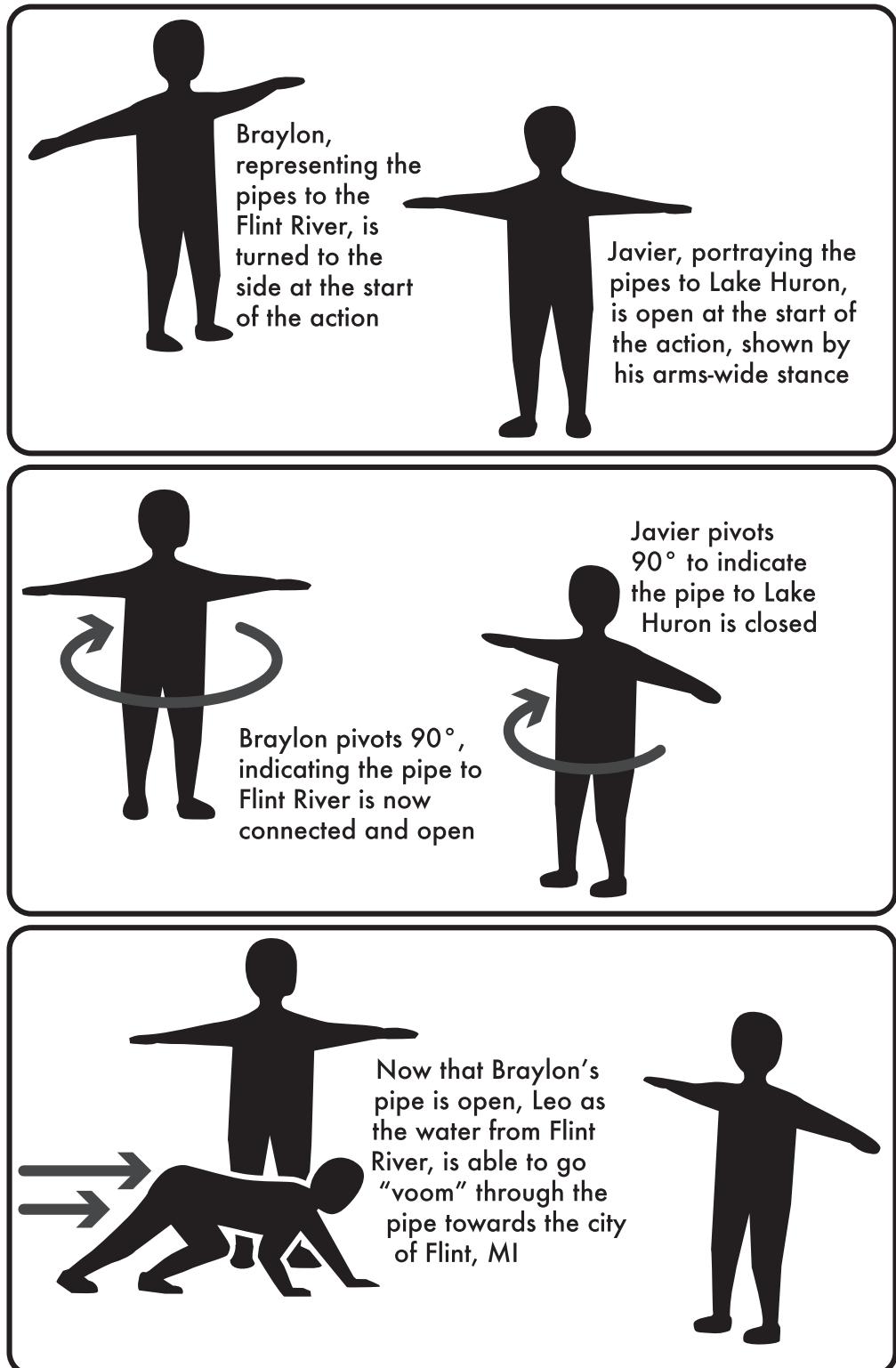


FIGURE 2 Sketches showing movements representing the water source switching. (sketches created by Ronan Rock).

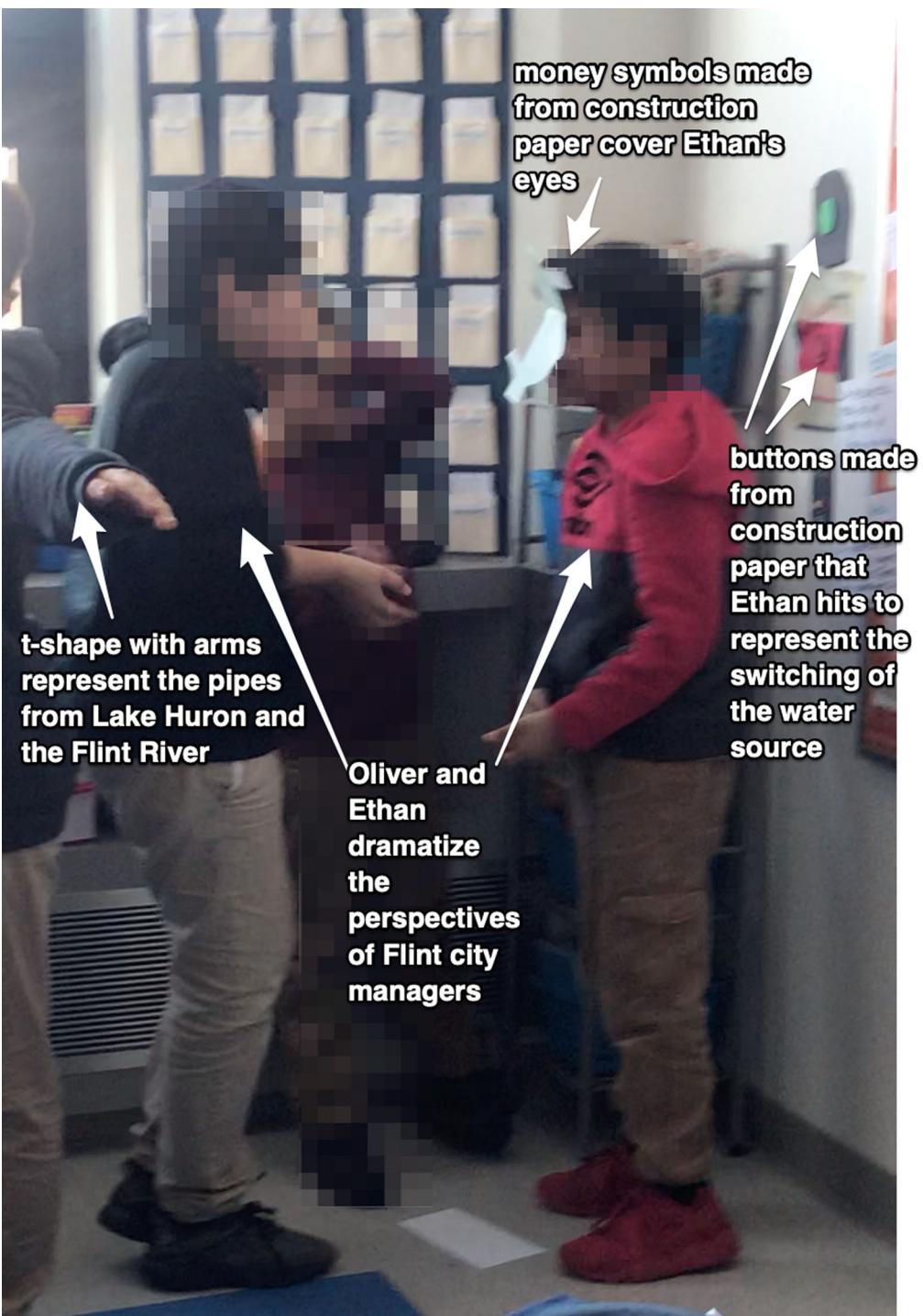


FIGURE 3 Taking on the roles of city managers.



the story they were telling, the audience was able to explore this perspective, adding it to the multiple perspectives they were exploring through each performance, in this case being made to *feel* the officials' disregard for human life.

Taking on different perspectives is a special affordance of devising theatre, and is made available to both the performers and the audience experiencing the performance. In this case, children took on and committed to various perspectives through embodied performances, notwithstanding whether these were perspectives of people, such as Group B, or entities, such as Group A, thus creating opportunities for ideational and affective responses to justice-centered ideas as they were working together to explore these perspectives. Rosario's commitment to expanding the structures of the classroom, to allow extended time to explore and plan enactments and ample time to perform and react to others' enactments, was supportive of representational agency, the naming and thematizing of the injustice, that dramatizing was affording to the children.

4.2 | Embodiment created space to further explore empathy and solidarity

Empathy and solidarity were explored in the fishbowl style discussion, but it was the dramatic enactment after the discussion that allowed for taking on first-person perspectives of the people of Flint, and empathy and solidarity with them. Lola and Yasmin brought up their responses to Flint with their classmates in the fishbowl, and then Lola's dramatizing group (Group C) explored these connections further through their embodied performance.

Lola had entered the class mid-year, after crossing the border from Mexico to the United States to live with relatives and Rosario marveled at how she was adjusting and at how many relationships she was forming with the other children. Rosario often encouraged her to speak in Spanish, which Lola was doing during the fishbowl. Empathizing with children who became sick in Flint and wondering if the government at least tried to save the children after figuring out the water was polluted, Lola asked, ¹ “Um ~ salvaron a los niños que están enfermos? [Did they [the government] save all of the children that were sick?].” Several classmates at once replied with a clear “no,” perhaps at this point convinced by classmates who argued that the government tried to cover up the truth. Those who usually spoke in English seamlessly continued the conversation in Spanish after Lola asked her question, signaling to Lola that they valued her contribution and the language in which it was spoken. Jorge explained, “Era muy tarde porque ~ el gobiernamiento no avisó a nadie ~.” [It was too late because ~ the government didn’t tell anyone ~] and then Ethan was quick to point out that once lead gets in the body there is nothing that can be done to take it out because it gets everywhere and eventually harms brain function. His developing representational agency seen in his thematizing and reasoning about the injustice of the city managers’ decisions, guided the discussion as he reminded his class, “El gobiernamiento sabía que ya, que había lead y plomo en, en la agua pero no les querían decir porque todos se iban a poner locos e histéricos.” [The government knew that there was lead in, in the water but they didn’t want to say anything because everyone was going to get crazy and hysterical.] Jorge doubled down on this, pointing out that because the government tried to keep the lead a secret for too long, the damage had already been done.

At this point, the level of affective energy had noticeably increased in the group. More students were sitting forward in their chairs with sustained attention when Yasmin, like Lola, wondered aloud about the children affected: “um ~ que no van a poder aprender tan fácilmente como otros” [they are not going to be able to learn as easily as others]. Lola and Yasmin, focusing on children affected by lead poisoning, prompted Ethan to wonder how someone with lead poisoning would experience it: “So what do you guys think about, so imagine yourself having lead in your body. How would you feel? How do you think you would feel?”

In response to Ethan’s invitation to empathize, which was catalyzed by Lola and Yasmin’s wonderments, Dante and David proceeded to debate whether or not you would know you were different from other people if you were impacted by lead poisoning. Particularly poignant coming from Dante, a child with a documented learning disability that impacted his writing in English and Spanish, was his comment that “what you might feel would be normal to you, but the other people on the outside are thinking you’re not normal.” For Dante, someone may not know their



learning was impacted by lead positioning because they feel "normal." However, David focused on the physical problems that lead positioning causes—"their teeth are falling, their hair is falling,"—and, thus disagreed with Dante, arguing that both the person impacted and others would consider these not normal. The two students were grappling with conceptions of what is considered "normal" and how these become internalized or assigned by others and used to determine mental and physical challenges. Rosario underscored Dante's point that everyone has their own understanding of "normal," and also that lead poisoning changes the human body in ways in which the body would not change without exposure to lead.

At this point, Alan's affective response to the lack of care the government had shown was palpable in his voice as he asked the class a question, and his peers digested the more emotionally charged turn the conversation had taken by stilling their movements. "Why don't, why didn't the government give respect to the people? He only cares about himself and the money?" The idea that the government was responsible for this atrocity sunk in more fully for Alan. He then reiterated his feelings, expressing his outrage that money could possibly be more important to the government than people's health. To this, Ethan responded, "The governor looks, here's an example. The government is like a human and us, the people who live in Flint, are like ants." Ethan, fully empathizing now with the people of Flint, positions them as "us."

The solidarity that the students were forming with the people of Flint and with their struggle for uncontaminated water was further strengthened through Group C's embodied performance, which included Lola, Dante, David, Jessica, and another student. We focus on Lola's contribution to the group's collective meaning making about how to embody the Flint Crisis from the perspective of a family, in which Lola played the role of a child. Focusing on Lola's progression from the fishbowl discussion to the embodied performance to her reflections at the end of the year brings attention to a progression of growing solidarity and empathy expressed by one student and also collectively through the dramatic performance she helped her group create. In the performance, using liter bottles, a book box, and a stick as props, Jessica, playing the role of a caregiver, stirred an imaginary meal in a pot. Lola and another student who played the role of another household member tried to decide which water to use by observing the water and smelling it, recoiling with gestures that suggested the water smelled and looked contaminated. At one point the three family members are huddled around the two plastic bottles as if they are deciding what to do about the family's water shortage (Figure 4). In the very next scene, these same family members are protesting with signs they made that read "The water is poisoned in Flint houses" and "We are poisoned and tired of drinking LEAD." This scene directly following the cooking scene, indicating the performers' growing understanding of the agency that becomes inspired and required in people who face injustices, taking matters into their own hands to demand restorative action. Lola, the child, is asked questions by the reporter, played by Dante, about why she is protesting (Figure 5). She explains that the lead is bad for her body and her mind, demonstrating her empathic connection with the children of Flint who were affected by lead, and her growing understanding of the rights and responsibilities to protest unjust and dangerous conditions.

Lola's end of year reflections reveal that empathy for others and gaining knowledge that could make a difference in young peoples' lives was an integral part of her developing science identity and what she valued and experienced as "scientific." Lola wrote:

Me sentí como un científico en el momento en que estaba aprendiendo sobre el cuerpo humano y sobre dónde el cuerpo y la mente han llevado al cerebro a efectar la mente de los niños pequeños. En donde me sentí que era pollution fue cuando estudiámos sobre el agua contaminada y el plomo en el cuerpo humano. [I felt like a scientist at the time when I was learning about the human body and where the body and mind have led the brain this effects the minds of young children. Where I felt I was scientific was when we studied about contaminated water and lead in the human body.]

Lola felt like a scientist when she was employing representational agency thematizing and characterizing the effects of lead on the human body, especially how lead poisoning affects young children. In the fishbowl discussion,

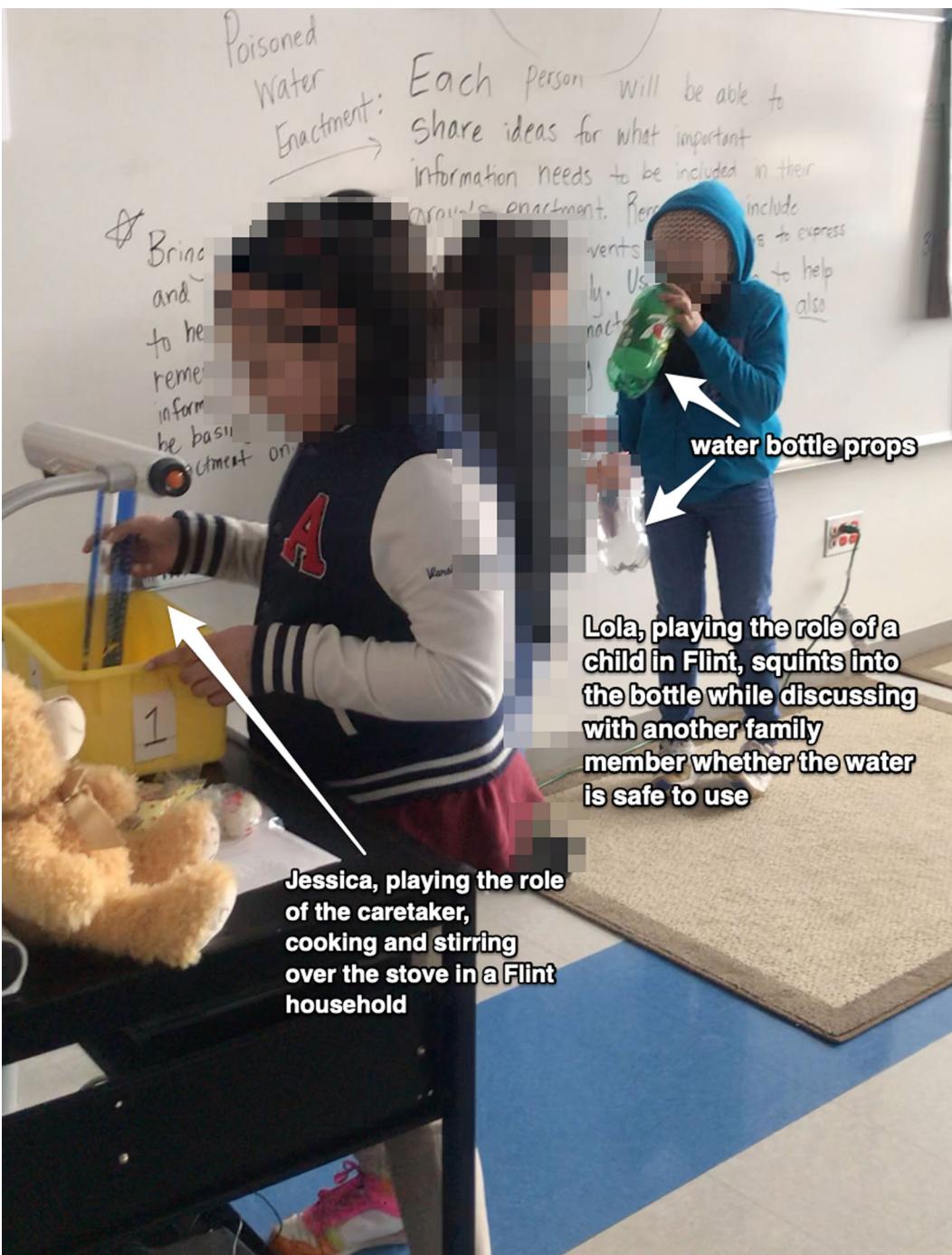


FIGURE 4 Dramatizing a family's clean water shortage.

Lola had been concerned about whether the Flint government was doing anything to help the children. Her classmates reasoned that the government made the situation worse by covering up their actions. In the imaginative world of the dramatic enactment, as a child in Flint dealing with the daily realities of cooking with contaminated water, she then controlled the stance she took through protest. Her residential agency was developing through the

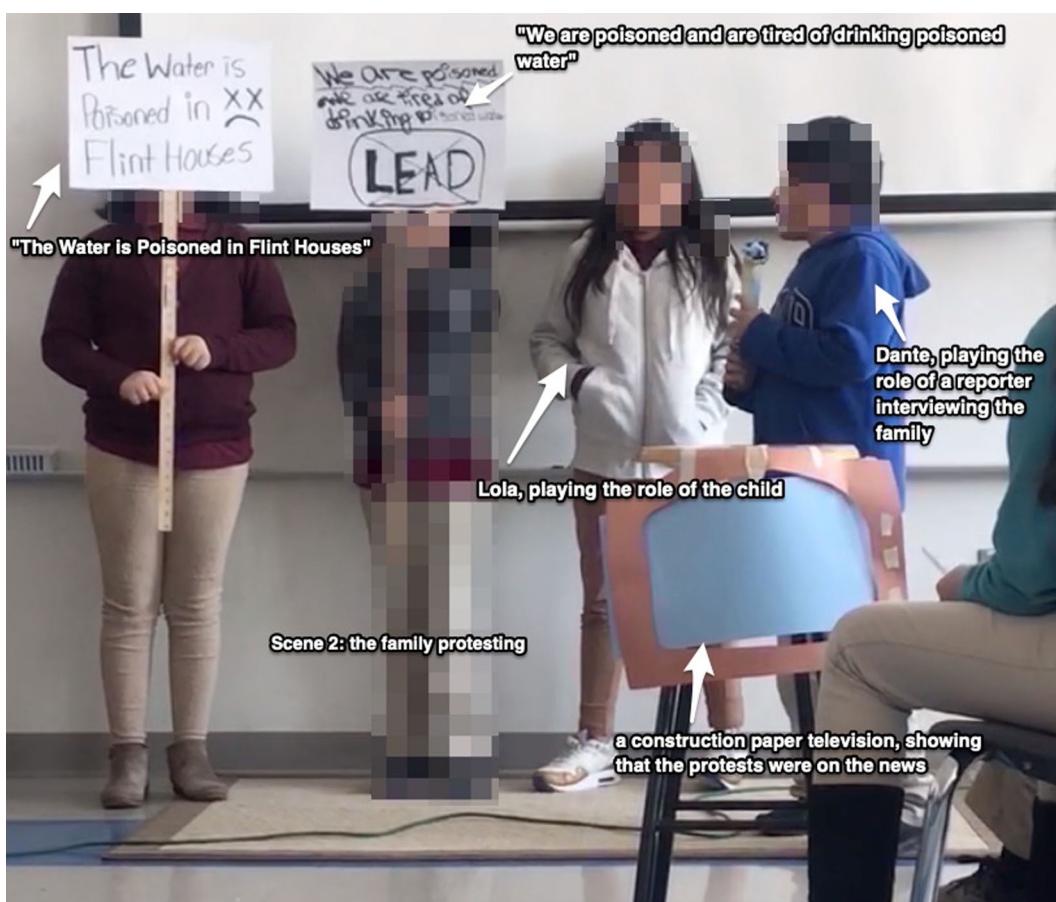


FIGURE 5 Protesting against the lead contamination of the water.

imaginative world of the drama, shifting from worrying whether the government was doing anything, which she voiced in the fishbowl, to expressing her own agency as a child in Flint to overcome the injustice of contaminated water, committing to action that would prevent the health problems caused from lead positioning. Over time, such experiences lead to the empathy that became intertwined with her developing science identity and her developing representational and residential agency. Lola had experienced several changes that year. Crossing the border, leaving her old home behind for a new home, and attending a new school. Her belief in learning as fundamental for people her age, and her concern that children who were affected by lead were being cheated out of so much learning, gave her a sense of solidarity with other children and through the dramatized protest she took part in, a sense of responsibility to use her knowledge to help others.

4.3 | Embodying catalyzed imagined and realized action in residential agency

4.3.1 | Imagining action

The students' written and oral reflections after being at the university theater and watching the play created by the sixth graders, revealed ways in which experiencing science in aesthetic, affective, and imaginative ways through



arts-based embodiment, not just their own but now through being the audience to others' performances, supported their development of representational and residential agency. Rosario discussed the play with her class once they returned to school and learned that the class had a collective positive response to the play. They expressed their surprise that students only 1 year older than them created and performed it and their newfound sense of responsibility to take action to combat the global pollution problem. Children expressed their strong affective and agentic responses to the play in various ways, aided by their ability to personally relate to the content because of learning about similar issues of pollution, specifically the Flint water crisis, which these sixth graders also presented in their play.

In their written reflections on what they took away from the experience of watching this performance, their representational agency (thematizing, characterizing, and reasoning about ideas) and residential agency (composing, controlling, and committing to actions) came through. David, who played a major role in shaping Group C's embodied performance of the Flint family cooking and protesting, as well as being an outspoken contributor to the fishbowl discussions about Flint, wrote:

After seeing the show now I'm thinking that there is a global problem. People are dying of pollution. Whatever pollutants like soil pollution, air pollution, water pollution and trash. Plastic is one of the main problems in the ocean if an animal eats plastic he will die. He will because the plastic covers the tubes and it takes more than 500 years to decompose. Also the problem in flint the water. I was contaminated with lead. Lead sticks in your body forever. In air factories are polluting the air. They have carbon monoxide which can kill you and pollute the air. Some cities are so polluted that you need to wear a mask. It is important to clean our home and take care of it. We could tell pre-k and kinder about how lead can kill you and not to drink from the washroom drink from the fountains.

David came away after watching the sixth graders' play with a dire understanding: pollution in all forms is causing death, both of human and nonhuman animals. Being an audience member for the sixth graders, together with his own experiences in Rosario's class, strengthened his understanding that lead is not just a contaminant but its effects last a lifetime because it "sticks in your body forever." But this seeming hopelessness was then supplanted by his expression of residential agency as he pivoted from identifying problems to composing what could be done about them and committing to why these actions are essential, both in terms of "clean[ing] our home [Earth] and tak[ing] care of it" and informing young children of how to minimize their exposure to lead.

David and his peers in Rosario's class had initially decided that as part of their 123 Action Project, they would create an embodied performance about lead to perform for the pre-kindergarten and kindergarten classes, based on what they learned from analyzing the city's lead report and finding out there were elevated lead levels in their own school water fountains near the kindergarten classrooms. They wanted to put on a play enacting what lead does to the body and what to do to avoid exposure to it. However, the class eventually decided that it would not be the right way to teach young children about lead, worrying that the younger children may start drinking less water out of fear they may develop from such a performance. They argued that they would not have enough time to work with the younger students in the school to minimize that fear, and therefore they did not think it would be wise to do this play for the younger children right before getting out for summer break. An embodied performance for younger children about the science of lead poisoning was one way to express their care for the world by bringing to others what they had learned so that together they could work toward change for people in their community. But deciding not to do it in a rushed way took to heart, in a responsible way, the younger children's potential fears. These fifth graders' thinking and decision about abandoning the idea they had come up with also provide additional evidence of their appreciation that embodied performances and plays are affective experiences where emotions emerge and get communicated in ways that words and images alone do not.

David's agency evolved over time. Earlier in the school year during the fishbowl discussion he revealed his representational agency sharing his initial disbelief that the government would willingly lie to people ("they lied?



They lied?" which was eventually shaped into a more critical understanding of the Flint officials' actions. He later imagined others' perspectives when he helped create the embodied performances of the Flint crisis from the perspective of a family cooking in their home and afterwards protesting the poisoned water they were forced to contend with, expressions of residential agency. David was also an active participant in exploring the lead study of his own city's school water fountains.

Similar to David's, Alan's representational and residential agency developed across the various curricular activities, from his questions in the fishbowl about how the government could do something so harmful to people, to his strong affective response to the sixth graders' play, which was associated with the value he was considering of such performances. Alan thought it would be important for others to watch the play, especially "the people that pollute." He wrote:

It [the play] would benefit to the people. The people that pollute should watch it so they can see how much damage it does to the world and they would notice what it does to people and what presidents do with pollution and so they could notice why should we keep the earth clean ... when I looked at the students [the sixth graders who performed their play] they looked the understand a lot why not to pollute our Earth. After seeing the show I'm thinking how important our Earth and why not pollute because there's not going to be a lot of animals and a lot of people can get really sick and a lot of people die each year and now how Earth is really important now we know a lot of stuff of pollution and we know how it starts and how it ends and with the pictures I was so surprised and it was so sad and I have a plan to stop pollution to put like a watch and when they pollute it gives them a warning.

Alan was moved by the play, especially by the images that were projected on the screen that made him "surprized" and "sad," feelings that can energize critical consciousness but also may weigh down on people, the reason the class ultimately decided not to perform the lead performance for the youngest students at their school. He was also struck by the science understandings of the sixth graders who presented the play—"they looked like they understand a lot." Developing science understandings was important to Alan and he readily shared ideas he was mulling over during class discussions. He often contributed his thoughts to the group and asked questions if he was puzzled by something. He was thoughtful and persistent in bringing forward intriguing ideas in class and was not shy about sharing his dismay at how the Flint government acted. Alan's own need to understand helped him recognize the representational agency in the sixth graders who performed and knew so much about pollution, through their embodiments, their script, and the images they had chosen. In bringing up presidents and what they could do about pollution, Alan expressed commitment to the idea that it is the responsibility of governments to combat pollution on a large scale and in systemic ways with the creation and enforcement of effective policies that protect the health of the planet. His developing residential agency through composing ideas of how violators, be they individuals, groups, or governments, may improve their polluting tendencies with a warning system, perhaps followed by more enforcement. In this way, he expressed that he was constructing representational agency through his own developing knowledge of the issues involved in pollution and residential agency at both individual and collective levels through imaginatively composing and controlling ideas that involved the use of advanced technology, something he showed at other times he was passionate about, to improve destructive polluting habits.

4.3.2 | Realized action

Through spectating and then reflecting on the sixth graders' play, the class engaged in imagining different visions of a future world depending on what kinds of actions were taken in the present. This kind of imagining could lead them to possible actions that could be taken to secure a healthier planet in the future. In addition, the students' activities and reflections within the 123 Action Project illuminate how their representational and residential agency, both



individually and collectively, was emerging while undergoing these recent experiences, embodied and performed for and by others, but also supported through the many embodiments they had done throughout the year. The developing representational and residential agency exercised by the children shine through the work and words of several of them—Yasmin, Camila, Leo, Sandy, and Dante.

Yasmin's knowledge and identity construction was particularly illustrative of the expansive identity roles and opportunities for agency supported through justice-centered science curriculum. In fact, Yasmin's identity shifts started to happen when the class began learning about the human body. Throughout this unit, it was clear that Yasmin's scientific curiosity grew as did her emotional connection to the learning content and her science identity became intertwined with advocacy and care for how lead affects childrens' brain function. Yasmin became concerned when she learned about children getting sick in Flint, which inspired her to do research, with her mom, about lead poisoning. She went home one weekend and studied lead poisoning with her mother and creating a poster, not assigned but rather by her own accord, to present to her class about how lead gets into the body and what it does to the brain. This presentation to her class built her growing confidence to speak in front of others.

Yasmin's newfound confidence, in turn, seemed to lead into a leadership role in putting the 123 Action Project presentation together, soon to be delivered in front of lawyers and peers, and she presented a strong emotional connection to the work for the project. It was Yasmin's influence on her good friend Camila, who at first did not want to narrate a slide during the presentation because she did not think her English would be good enough to speak in front of lawyers. Yasmin convinced her friend to participate in Spanish, pushing back on Camila's assumption that the presentation had to be delivered only in English. Rosario discussed her pride in Yasmin for giving her friend the confidence to be part of the presentation and for developing her sense of agency even further, pushing back against structures that implicitly and explicitly made Camila think that English was the only language to use in front of the lawyers. Incidentally, the lawyers ended up thanking Camila for presenting in Spanish, mentioning it as a particularly moving, powerful moment in the presentation, reflective of how critical translanguaging practices are in creating equitable science education.

Another manifestation of equitable science education was voiced by Leo, for whom enactments of science ideas made it possible for the class to learn complex concepts related to lead pollution and how it gets into the human body. After the class finished their 123 Action Project presentation, Leo took a question from a member of the other class, which attended their presentation, on how they came up with their idea to do a project on lead. Leo responded, "Actually in science, we started enacting so we made our science easier, and then we read articles and then we interpreted them by acting and showing how lead and pipes worked and what happens when lead gets into the water and body systems." Embodied performances made "science easier" and meaningful, bridging texts they were reading with their performances. In fact, collectively, this feeling that embodied performances were important learning experiences was shared by the class as evidenced by the inclusion in their presentation of a video recording of Group A's lead contamination enactment from within the Flint pipes (Figure 6) accompanied by text spoken while projecting the slide, which Leía shared at the presentation: "Our class practiced acting out science topics like the one about corrosion control, in order to understand it better. These enactments make learning science fun and helps us to understand difficult topics in science."

Not only was Leo aware that acting out science made science "easier," Leo was also developing his residential agency through committing to affect positive change, and a strong science identity in which composing, controlling, and committing to actions were being considered important and valued. Leo was consistently engaged in embodied performances, like when Group C was planning their enactment of the government switching the water source in Flint. The importance of the 123 Action Project presentation to Leo's science identity became clear in June:

I felt like a scientist when I went to present the information that we learned at the university. I felt like a scientist because scientists present what they learn to people that can help him/her make their ideas into a reality.

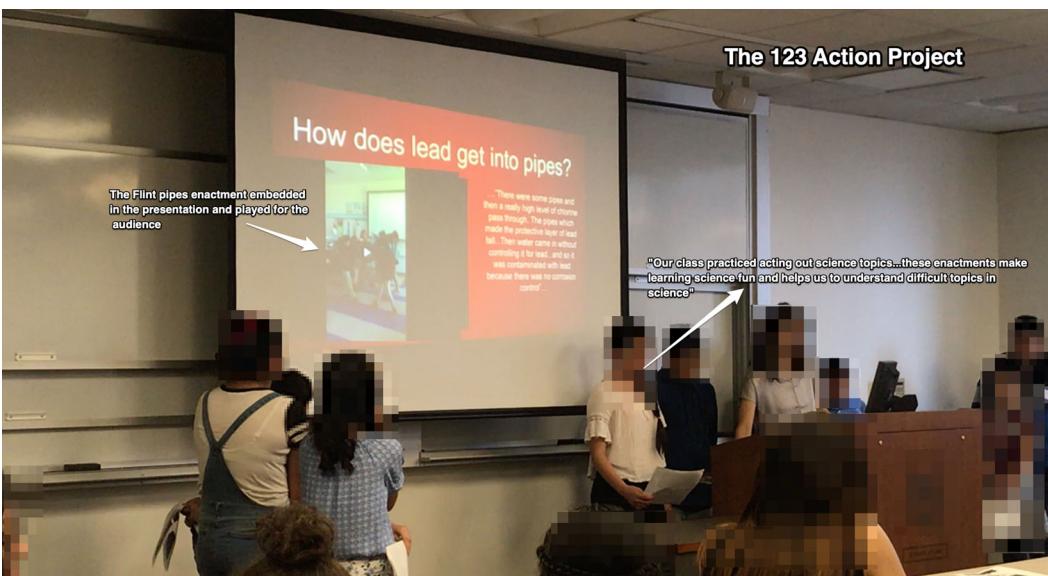


FIGURE 6 Students presenting their 123 Action Project and referencing their enactment of the lead contamination of the water in pipes.

At the end of the year, Leo saw the value in his science learning, as he positioned himself as an informed scientist who had “information” to share with others, he also acknowledged the communal nature of knowledge production—scientists help each other to further develop their ideas so they can be more impactful.

Sandy reflected Leo's pride in sharing useful information that could make a real difference in peoples' lives, as seen through her reflection of the experience struggling alongside her classmates for improved environmental health conditions: “It's like saving many people. Twelve people have died and our class wants to save more people. We want to have a better life, not like in Flint.” What fascinated Sandy about the project was “that we sent cards to the mayor and we came here to talk to the lawyers who work in the government. That, it's hard but if you try and try you can get something to happen. I was happy because our class got to help.” Sandy's science identity was intertwined with committing to collective actions and a collective activist identity, using “we” to place herself in collective struggle with the rest of her class, reducing the distance to Flint in realizing that she and her classmates are living the disparities of lead contamination as well.

Dante's science identity work toward the end of the year also became increasingly focused on using his agency to combat pollution. He focused on advocacy around pollution and disseminating what he knew to others that he wanted to protect. He wrote in his reflection on the sixth graders' play that “we must vote someone who care about pollution.” For Dante, science was connected to the sociopolitical world and through this statement he reveals emerging political clarity (Freire, 1998) that elected officials should support environmental protections and policies consistent with science knowledge. At the end of the school year, Dante wrote about his disseminating of science ideas to others, an important new aspect of his science identity. He wrote that he felt like a scientist when, “I explained to my parents of lead and explain that the tubes [pipes] and everywhere there's lead.” He also felt like a scientist during the letter writing campaign portion of the 123 Action Project “because we explained about lead and it felt like a scientist. We explain about we need so much to stop lead like the Coda (pseudonym for a system the students had discussed) that the schools need to stop lead from increasing.”

In their letter writing campaign, several other students mentioned the Coda water flushing system that Dante referenced, which they learned about when Rosario found a story about a Latino school building engineer who had invented a system that he called the Coda to automate the process of constantly flushing water through the pipes,



preventing stagnation that breaks down the protective coating that the harmless orthophosphates added to the water have built up in the pipes. The class was impressed that this flushing system had resulted in low lead readings. A fellow city dweller who shared their ethnic identity as Latinx had developed a solution for a problem that their community was facing too. The students decided to each write letters to school allies, including the city mayor, the school superintendent, and the state governor, to bring their attention to the lead levels found in the 2016 report and advocating for schools to take more responsibility to protect children from lead exposure, including recommending reusable water bottles and installing the Coda device (Figure 7). Rosario recalled later that the children were impressed that this engineer was not only showing up for work every day but was a true problem solver and inventor. As their own agency was developing around issues of water pollution, they thought it was amazing that this engineer had invented a solution and felt the responsibility to make sure that elected officials would hear about what he had invented from them, so they would consider putting his device in all of the schools in the district.

The embodied performances situated within the justice-centered science curriculum that the class designed and enacted themselves, and those they watched sixth graders from another school perform, were front and center in their development of both representational and residential agency. By learning, in justice-centered ways, about Flint and about their own city, the children became positioned as scientifically knowledgeable allies and activists in their community. By researching lead data in their own school district, researching solutions, and writing to officials such as the governor and the mayor, they began to appreciate the complexity of these problems but also began to find hope in planning their collective actions to share their knowledge with their community with an organized approach to knowledge dissemination. By participating in a letter writing campaign and doing a formal presentation about what they learned, Rosario used her own agency to expand curricular structures to include opportunities for community advocacy and arts-based performance so that her class learned to advocate by actually doing it. By

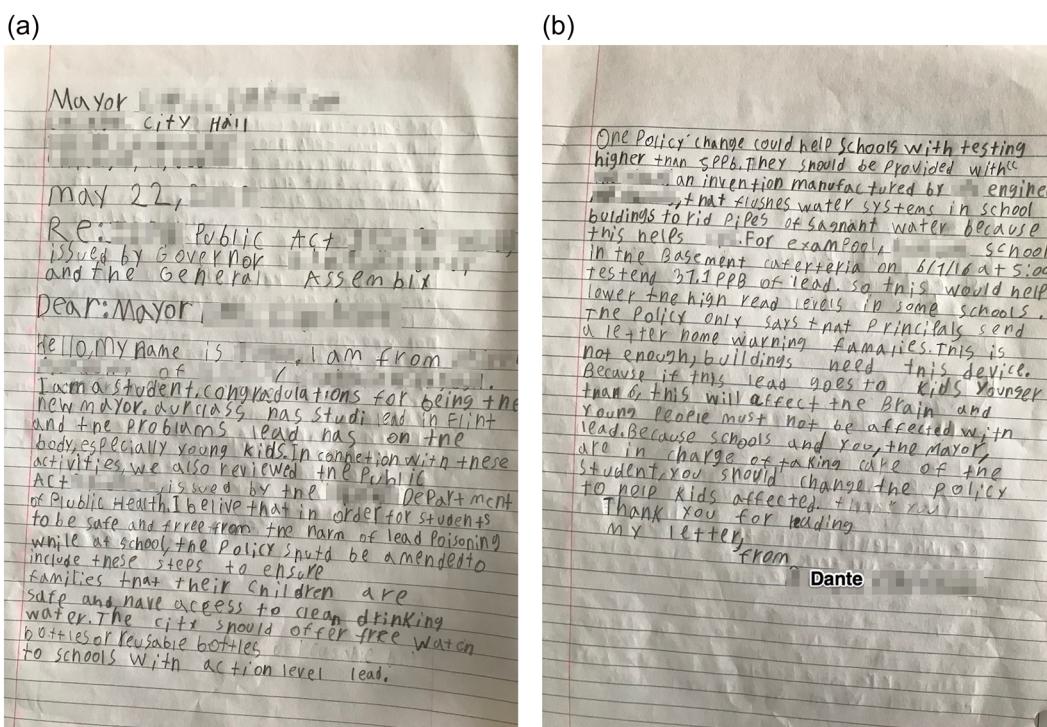


FIGURE 7 (a) Page 1 of Dante's letter. (b) Page 2 of Dante's letter.



writing letters to allies and presenting their ideas to lawyers involved in public policy, their representational and residential agency was developing individually and through collective action. One lawyer at the end of their presentation told them she worked on major city policies in the mayor's office and would be sure to share what she had learned from their presentation, which she had never thought about before. This comment from her was proof that their advocacy work was getting noticed and could make an actual difference, an important aspect of critical science literacy.

5 | DISCUSSION

There is evolving interest in science learning that develops elementary school children's agency to knowledgeably act on environmental justice issues. It is often assumed that, because of their age, elementary-age children will be fearful when presented with environmental issues, despite being capable of complex and nuanced social justice learning (Davis & Schaeffer, 2019). In fact, this was the fear the fifth graders thought they would give rise to in the kindergarten class if they went ahead with their original idea to present an embodied performance about lead to them. However, the present study provides evidence that arts-based embodiment gives Latinx elementary school children, who have been historically minoritized in various ways in US science education, a productive form of engagement with justice-centered science.

Science identities develop over the years of accumulated opportunities to do science identity work as part of science identity trajectories (Johnson, 2012), and cultivation of agency (representational and residential) to problematize and act against limiting structures plays an important role in this identity work (Varelas et al., 2015). If we intend for young people to develop trajectories that include well-developed science knowledge that can be put to work in the struggle for justice for all people's quests for and rights to unpolluted resources, we have to create agency-rich opportunities like the arts-based and multimodal projects the classroom in this study undertook. These opportunities in elementary years could lead to developing identity salience, which is developed through social ties and connections one accrues while enacting this identity across contexts and activities (Stryker & Burke, 2000).

At a time when science education is being charged with the task of widening forms of engagement and equity, providing expansive opportunities for children to do science and identity work in science in ways that embrace children's brilliance, agency, and creativity (National Academies of Sciences, Engineering, and Medicine, 2021), arts-based, embodied practices forge inroads for children to think, feel, and imagine with critical scientific literacies. Education in these times is also being called on to promote critical literacies for civic engagement in public life (Lee et al., 2021). The performing arts create unique opportunities to explore civics and social action and need to be further explored to meet the call for civic engagement (Silva & Menezes, 2016). These two calls, one in science education specifically and one in education more broadly, bring to the forefront the ideas of aesthetic education that were sidelined for several decades in the era of accountability. Aesthetic education can help us consider how imagination developed in and through the arts can help children see possibilities for justice, developing their individual and collective agency to challenge us to see the possibilities of the just worlds they bring into being through imagined and realized action. First, we will draw conclusions based on the major findings of the study and offer some additional theorizing to help illuminate each of the findings. Next, we will offer implications for research that centers the work of teachers and teaching based on what we noticed during the study. Finally, we will offer some closing thoughts meant to sustain all of us in this important work.

5.1 | Conclusions

By exploring arts-based embodiment and its facilitation of a science curriculum for elementary learners that centered moving their own bodies as sites of learning justice-centered science, we wanted to know *how* children



engage with arts-based embodiment strengthening children's sense of agency through the affective, ideational, and social practices of justice-centered science. Practicing teachers' professional knowledge includes an understanding that drama helps with learning in various disciplines. Teachers use drama pedagogies to increase engagement across the curriculum, and our study in some ways underscores what is already known: that drama and embodied approaches, in general, help us learn. However, our specific goal with this study was to uncover the ways drama and embodied arts-based approaches strengthen justice-centered science to hopefully encourage more elementary educators to bring these approaches to their own justice-centered curricula and lessons and to encourage more research in this area.

Social justice science education and the structure-agency dialectic contextualized the exploration of how the children used their bodies as sites of knowledge construction and positioning in science as they engaged with justice-centered ideas. Our analysis surfaced three functions of arts-based embodiment and multimodal communication, more generally, to engage children in justice-centered science, and those are: allowing for multiple perspective taking, nurturing children's feelings of empathy and solidarity with those who struggle for just environmental conditions in their communities, and catalyzing children's imaginative and realized actions with respect to environmental injustices, supporting the development of representational and residential agency.

5.1.1 | Arts-based embodiments and issues of equity and justice

We found that creating arts-based embodiments of science allowed children to take on perspectives, through the metaxis involved in dramatizing, of the entities and people directly involved in the processes. These shifts in how children were experiencing the ideas, by moving their own bodies and using their own voices within the processes themselves, were supportive of robust understandings of the science and justice ideas and became foundational for their developing representational agency. Taking on characters of entities and people and dramatizing these roles could be seen through the heightened emotions and vitality happening in the groups as they planned and rehearsed, the risk taking of putting ideas forth and negotiating them together, and the imaginative work involved in making semiotic choices, such as using construction paper to represent lead, protective coating, money symbols over the eyes of rapacious officials, and signs of protest. In these ways, an arts-based embodied pedagogy allowed children to explore how science and the social world intersect through "enacting conditions of possibilities, interruptions, interpretations, and play(ing) with variable relations" (Fels & Meyer, 1997). Enacting science ideas with their bodies and with each other, and involving their emotions in science in ways that western philosophical traditions since ancient times have relegated as unscientific and irrational (Zembylas, 2002), allowed them to grapple with their understandings. While they were enacting, they were also clarifying their understandings in communication with each other, a particular affordance that is offered when students construct their own representations of science ideas (Prain & Tytler, 2013).

Often, the meaning making of young students who are early in their development of scientific language or who are emerging bilingual students, like several children in this study, get ignored when speech and written communication are held up in science classrooms as the standard way we construct and communicate meanings and when embodiment is ignored as a mode of knowledge construction and communication. However, we learn new words and their meanings through experiencing them, in that "situated meanings are, crucially, rooted in embodied experience" (Gee, 2008, p. 164). Thus, in embodied performances, meanings are experienced in our bodies and negotiated among groups of children which benefits children's language development (Ntelioglou, 2011). Our work rests on the belief that multimodal engagement is not only a matter of our own "generosity of recognition" (Bezemer & Kress, 2015, p. 5), but is an imperative of equitable teaching and learning so that all students' brilliance becomes foundational for their continuous learning. We enact this belief by taking the meaning making, both in terms of constructing and communicating ideas, of children seriously in all modes, including embodiment, to "problematize the privileged forms of science" (Philip & Azevedo, 2017, p. 528). These commitments expand what



counts as science practice, understandings, and identities and in these ways promote equity in science. By framing children's embodiment as a resource that is central to learning in the discipline of science, arts-based embodied pedagogies in science classrooms can thus become a catalyst for "rightful presence" (Calabrese Barton & Tan, 2019), an equity framework defined as "legitimate and legitimized membership in a classroom community because of who one is (not who one should be), in which the practices of that community support restructuring power dynamics toward more just ends" (p. 619). In these ways, multimodal and arts-based ways of learning science serves to expand science education practice so that more children can see themselves doing science brilliantly and in many different ways.

5.1.2 | Devising theatre and critical emotionality

We also found that embodiment nurtured and supported the development of empathy and solidarity with children who were adversely affected by lead. In fact, the recognition of emotions is thought to be essential in the struggle against injustice (Zembylas & Chubbuck, 2009), and this is exactly what happened when children embodied the different perspectives of the Flint water crisis. Individual children expressed their emotionality and their developing science identities in various ways. Dante, empathizing with those affected by lead partly or because of his own experience with a learning disability, argued that perhaps to the person affected by lead, this is who they are as they face the "pernicious standards of worth associated with the fully functioning self of contemporary society" (Goodley, 2013, p. 640), questioning, in his way, "attempts to maintain what Campbell (2009) terms 'ableist normativity'" (p. 637). Yasmin expressed care for the children impacted by lead in Flint and went home and learned as much as she could about lead, involving her mother, and then brought her research back to the class to share what she had found out. Ethan asked his class to imagine what it would feel like to be poisoned with lead and positioned himself and his classmates, along with those struggling in Flint for justice as "us." As affect and emotions were deeply experienced in embodied ways, both individually and collectively (Lenters, 2018) among members of the class, the children's embodied performances became spaces and places to construct, for example, for Lola and Yasmin, identities as advocates for people's rights to healthy lives. Their science identities expanded as they included empathy and advocacy, intertwined with understanding the mechanisms of lead poisoning in the body, and as they noted that the Coda inventor was a Latino like them. The students' science identities were supported when emotionality and perspective taking influenced, and were influenced by, their developing science knowledge. Younger students are often deprived from digging into understanding, problematizing, and interrogating troubling aspects of their and other peoples' lives in both physical and social worlds, and imagining different futures. Davis and Schaeffer's (2019) study of how Black children conceptualized the Flint water crisis over time, showed how the students became increasingly able to connect the water contamination in Flint to the local issues associated with water distribution in the majority Black city in which they lived. Similar to that study, the present study shows examples of young Latinx children experiencing justice-centered science curriculum in profound ways, with a sense of agency and hope.

In fact, embodied practices affording a sense of empathy and solidarity through taking on the first-person perspective could be seen as forms of "critical sentimental education" in which "action-oriented empathy" is the goal over "cheap or empty sentimentality" (Zembylas, 2017, pp. 1–2). Critical sentimental education requires "both criticality and affective engagement" (p. 15), which we saw happening in the various curricular events in this study. While we acknowledge the importance of children never claiming that they can fully experience another's pain (Zembylas, 2013), we have to allow children the opportunities to learn of and feel empathy and compassion for struggles of an environmental nature so that they can learn that they can act on behalf of their communities as well. Embodying these struggles in action and in imagined ways through the arts can close the distance that is common for people to feel when they learn about environmental issues and struggles (Moore & Milkoreit, 2020) and help them feel that solidarity. After all, feeling sorry for others, without solidarity and empathic emotions can lead to a



feeling that there is nothing that can be done and that these problems are too big to fix, which is a deeply colonial mindset (Moore & Milkoreit, 2020). "Pity, compared with compassion, distances; indifference deadens inclinations to respond" (Greene, 1982, p. 6). However, there is a growing interest in how the "climate related arts" facilitate a cultural turn and allow young people to speak out about the sustainable futures they need to imagine (Galafassi et al., 2018).

5.1.3 | Imagination and agency

Lastly, we found that embodiment contributed to imagined and realized action and nurtured the children's representational and residential agency as they explored multiple perspectives and took action. We see the "more powerful and just forms of educated action" (Calabrese Barton, 2015, p. 450) as supported by valuing knowledge construction, which includes thematizing, characterizing, and reasoning about the injustice, and imagining alternatives through controlling, composing, and committing to action as powerful forms of agency, enabled through the performing arts. The creative process that gets enacted through the devising process may allow children different ways to engage in "micro-acts of self-determination" (Davis et al., 2020, p. 2). Teachers have agency to create pedagogical and curricular structures that are enabling for their students (Varelas, Tucker-Raymond, et al., 2022). When teachers structure science learning to include expansive opportunities for children to both do and communicate science via the performing arts, and when they seek out opportunities for their students to perform their knowledge and be positioned as knowledgeable community activists, "contested spaces" (Kane, 2015, p. 462) get negotiated and transformed. In a learning environment supported by their teacher's continual development of her own scientific understandings and agency, children learned that they could talk to powerful interests through a letter writing campaign and presented their learning, and the valuable role that embodied performances had in it, to a room of lawyers who worked for the city and made policies. Rather than becoming overwhelmed and inactive in the face of the injustice they were coming to understand, through their embodied participation they epitomized Freirean (2006) *critical hope*—"Alone, [hope] does not win. But without it, my struggle will be weak and wobbly. We need critical hope the way a fish needs unpolluted water" (p. 2)—as they imagined and demanded unpolluted water. Greene (1982) wrote of agency catalyzed through the arts in a piece in defense of public education: "I want to see imagination released and openings found for the arts ... so that young people will be enabled to look out beyond the actual and the given and summon into being alternative worlds. I want to see alienation and fixity give way to participation and movement, the free play of movement, the free play of thought, all for the common world" (p. 9).

This movement to the common world necessitates both imagination and its two functions—"understanding the present and envisioning the future" (Moore & Milkoreit, 2020, p. 6) and its relationship to agency. Such imagination and agency need to be cultivated over long time scales, starting to do this work with children as strengthening agency takes time and goes through many phases. Moreover, we need all the time we have to do the necessary work in science education to contend with the Dominant Social Paradigm (Feygina, 2013), which reflects deep-seated ideologies of consumption and disposability, along with domination and control over the environment, which can be viewed as a "manifestation of a broader process of injustice and subjugation perpetrated by the rigid and steep hierarchies that structure contemporary society" (pp. 368–369). Challenging all aspects of this paradigm in our work in science education with children is necessary for a foundational sense of justice, critical hope, imagination, and transformation.

5.2 | Implications for research and practice

This study offered a glimpse into the intersection of justice-centered science, arts-based embodiment, and multimodal approaches in science education. Future research could explore how children's representational and residential agency develops and gets nurtured when embodied performances can be shared outside of the



classroom walls, in community spaces. In what ways can students help community members name injustices, empathize, and act on environmental struggles through embodied performances? Since imagining just futures involves more than rational thought, and relies heavily on emotions and imagination, how can children help community audiences envision just futures through theatrical performances? Another needed direction for future research is related to teachers' perceptions and practices of justice-centered science in elementary grades and the affordances that arts-based embodied practices offer. We need to learn from teachers as they do this work, both in terms of their students' and their own knowledge and identity construction. Elementary school teachers are usually restricted by school schedules and expectations, limiting creative work, which usually does not center science learning, to unfold in all of its messiness and nonlinearity. Rosario was an exception in many ways being committed to providing extended time and searching for "cracks and fissures" (Carlone et al., 2015, p. 476) in classroom and school structures to make this possible.

Despite the limited scope of this study, several recommendations emerged for teachers poised to explore justice-centered science with children through the arts. For classroom teachers, creating space for embodied performances is a considerable pedagogical commitment and takes careful planning and consideration of the curriculum as a whole. For teachers already teaching science in justice-centered ways or already bringing performing-arts pedagogies in science, integrating devising theatre processes to explore science topics from different perspectives could be beneficial. Focusing on the quality of each performance is not necessary and detracts from the main benefits that we consider being the devising process itself and the reflections that follow. For teachers new to either justice-centered science or performing arts in science, progressively moving along in small steps could be the key—integrating practices throughout various units and noticing how the class is responding as students get more and more experience with the devising process of: thinking up many themes and perspectives related to a justice-centered science topic, breaking into groups and creating and rehearsing a performance, performing, reflecting, and even revising after the reflection to improve the performance. This can happen over several class periods and could be integrated with language arts, social studies, and math to find more uninterrupted ways to allow children the time needed for the devising process.

For teachers who choose to bring arts-based embodiment into their science classroom, starting with small and incremental moves may be most practical. For instance, while reading science texts aloud, teachers could enact movements and ask the class to do their own and explain them to each other. After much practice moving their bodies to show science ideas, small and whole groups could try more coordinated performances to explore science ideas and processes, or to explore varied perspectives—as in the example from Rosario's class. Embodied performances at various scales in the classroom can be scaffolded and potentially lead to performances for broader school and community audiences as teachers embrace arts-based embodiments and make commitments to use them as ways to support justice-centered science approaches. Most importantly, teachers need to "legitimize" and "normalize" movement in science by modeling it and by supporting the embodying they see, which could show particularly reluctant students, who have experienced science education, and education in general, in ways that limit movement of their bodies, that moving in science is a celebrated form of meaning making intrinsically linked to action and agency.

Embodied performances have the potential to transform science classrooms into spaces of exploration and places of belonging where the students' whole bodies are part of the journey as much as their minds, but for these experiences to become meaningful, students need to be continually guided to reflect with their classmates and teacher on embodied performances. The imaginative work involved in embodied performances of science, including justice-centered science ideas, invites children to enact culturally relevant pedagogies (Ladson-Billings, 1995) by bringing their multiple identities and ways with science together in ways in which one knowledge system is not exclusively valued over another. Structures are not fixed, and students and teachers can shape structures and recreate them (Kane, 2015; Rodriguez, 2015).

This study's significance for science education is that it illuminates the functions of arts-based embodiment in justice-centered science, helping students' construct and express sophisticated science knowledge, identities that



are not necessarily in conflict with other identities, emotions, and agency. The explosion of communication and aesthetic engagement that can happen in science classrooms when children are allowed to express themselves multimodally, through their bodies and words, opens windows through which teachers and children can be creating and revealing their understandings and their feelings about what is happening in the world. There is a critical level of engagement and understanding that is seen in the general public when science becomes expressed and felt through the performing arts (Schwartz, 2014). We saw similar levels of engagement with the children in this study as they performed science and sociopolitical ideas. Understanding the affordances of arts-based embodied learning in science compels science educators and researchers to embrace these ways of learning and being in science education settings to involve children and communities in environmental justice. The arts spark imagination and feed our collective hunger for agency to get involved in envisioning and enacting solutions that will protect and improve lives.

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The data are not available due to privacy and ethical restrictions.

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ENDNOTE

¹ “~” Indicates a short pause in the speech.

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