# Embodying Science:
# Latinx Children's Knowledge and Identity Construction While Studying Water

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## SUMMARY

Students come to school with interest in science and rich resources for learning science, yet opportunities for meaningful science learning often fall short. Science education is often dominated by rational activity and the body is not often considered a site of knowledge. This study explored how *embodied performances*, defined as drama- and movement-based representations of science ideas that are either spontaneous or rehearsed, afforded construction and communication of science knowledge and identities among Latinx fifth graders within the context of a year-long water curriculum that addressed issues of sustainability and justice.

The embodied perspective central in this study has been shaped by embodied cognition, social semiotics, multimodality, aesthetic learning, and drama pedagogy. It embraces the idea that the body is central to meaning making and not just in the service of speech or in need of control in the service of rationality, meanings are socially constructed and exist in dialogic relationships in ways that are highly contextual, and the cognitive and affective dimensions of experience are amply intertwined. This embodied perspective is coupled with a science learning perspective embracing sociocultural approaches to meaning making, identity theory, and justice-centered science education. It considers identities as roles that learners have and take in various groups and communities, identity construction as an inseparable part of learning along with knowledge production, and science knowledge as ideas about both natural phenomena and their intersections with the sociopolitical world.

The goal of the instrumental case study research design was to understand how science learning, defined as both constructing science knowledge and constructing science identities, shaped student engagement in embodied performances of science ideas, and in what ways participating in embodied performances of science ideas was shaped by science learning. Multimodal discourse analysis of video-taped classroom lessons and conversations with the students, along with artifact analysis, were used.

Children in the study transduced meanings across various modes and translated meanings within the same modes, extending each other's thinking and building ideas in collective ways. They engaged in sophisticated meaning making of science ideas in various modes, such as gesture, whole body movement, drawing, dance, and props and costumes, as they were afforded opportunities to use their own bodies and other multimodal tools and resources to construct and communicate science ideas. As they communicated multimodally, and in embodied ways, they further clarified their ideas but also positioned themselves as people who engaged with science, felt good about themselves and their science learning, and supported each other.

Children made meanings dialogically during reflections on embodied performances. These reflections turned out to be one of the most important parts of the process because the questions that children posed led to greater understandings and expanded opportunities for children to be recognized by their peers for their contributions. These periods of extended dialogue during and after embodied performances offered distinct affordances to performers and audience. The performers benefited from hearing the audience interpretations and confusions, while the audience benefited from seeing the unique way of representing the ideas put forth by the performers.

Furthermore, multiple embodied performances of the same science concept offered a heightened level of engagement because many interpretations became possible and comparisons could be made across different performances. Each group's performance could not contain all ideas related to a particular concept, thus different embodied performances allowed multiple ideas to be considered collectively. When children were empowered to construct multiple embodied models of a concept, with few parameters other than to include movement and interaction, ingenious ways of bringing abstract scientific ideas came through pointing out unique aspects of each idea.

Finally, when children took on perspectives different from their own, whether these were perspectives of people, entities, or processes, they were engaging with the ideational, social, and affective dimensions of producing and communicating science knowledge. Perspective-taking engaged children in not only considering science ideas about lead contamination of drinking water but also developing critical consciousness of policies that impact health, and agentic identities that embrace caring, advocacy, justice, and peoples' rights to healthy lives.

This study suggests that future research should continue to interrogate how embodied ways of enacting science knowledge and identities can extend what counts as science. When children spontaneously move their bodies, often by gesturing, to represent science ideas, or when they rehearse an embodied performance and share it with their classmates, an explosion of communication and knowledge construction could emerge. Thus, teachers would stand to learn much about their students' understandings as they watch them engage in science while experiencing the joy that comes from connecting ideas in social, collective spaces in which their whole selves are invited to participate. Researchers and practitioners at the crossroads of science, performing arts, and justice-centered pedagogies need to probe more deeply into the particular affordances that embodied performances offer in the exploration of science learning.

# I. INTRODUCTION

Science has the potential to excite the imagination of children and to inspire broad engagement in learning about the natural world and peoples' interactions with it. However, opportunities for meaningful learning often fall short when children get positioned as passive recipients of established scientific knowledge. Positioning students in this way has contributed to students' dis-identification with school science, particularly those who affiliate with historically minoritized groups (Aikenhead, 2006; Calabrese Barton & Roth, 2004; Lemke, 2001; Seiler, 2011). Embracing sociocultural, cultural-historical, and sociopolitical perspectives implies rejecting deficit-oriented thinking and recognizing students as "cultural and whole people" (Calabrese Barton & Tan, 2020, p. 4), social beings involved in many cultures and subcultures that influence their engagement in school science. Such perspectives necessitate examining science engagement "both within and beyond the classroom" (Lemke, 2001, p. 305) and "work[ing] more vigorously against the radical separation of school from the rest of students' lives" (p. 310) in order to help students make meaningful connections to science. Classrooms should be considered spaces in which students' everyday knowledges and experiences are treated as intellectual resources for learning science (Bang et al., 2009). In these spaces, students are involved in socially-mediated, dialogic processes that stimulate group engagement with, and reflection on, science ideas (Tobin, 2012; Varelas et al., 2008), and they build knowledges including sociopolitical understandings and construct science identities in both collective and transformative ways (Varelas et al., in press).

Even though science education research has increasingly embraced sociocultural and cultural-historical learning theories, that is, learning as a social and cultural enactment (Tobin, 2012), transmission learning is still widely practiced. Students come to school with interest in science and rich resources for learning science such as community cultural wealth (Yosso, 2005), funds of knowledge (González, 2006), and full semiotic repertoires (Suarez, 2020) and yet they are often not engaged. Students may experience school science as a compendium of facts to be learned, rather than a creative enterprise to be examined and engaged with, which points to a disconnect between practices in school science and scientists' practices (Schmidt, 2011), in addition to science in their social and cultural worlds. Practicing scientists describe the creativity and emotionality that is involved in understanding processes that we cannot see or experience in the everyday lived world and children engage in such endeavors as part of their everyday lives (Warren et al., 2001), but school science is not often taught in engaging ways that require creativity and activate the affective domain to support students' science learning.

Moreover, science education is dominated by rational activity and the body is not considered a site of knowledge in its own right (Wilcox, 2009). However, children construct both deep scientific understandings and positive science identities through involvement of their whole bodies in the sense making process (Varelas et al., 2010). Embodied pedagogies broaden the semiotic systems that get enacted in classrooms and help students view science as a creative endeavor as well as form more affective and personal connections to science (Butler, 1989). I define *embodied performances* (Kotler et al., 2019; Varelas et al., 2010) as drama- and movement-based representations of science ideas that are either spontaneous movements, often expressed by gesturing, or intentionally rehearsed movements that are then performed in the classroom. Embodied performances align with, and further expand, sociocultural and cultural-historical perspectives of science education, engaging students' everyday understandings and providing socially-mediated experiences in which collective sense making is valued. Multimodal, embodied approaches to learning are prevalent in other areas of the curriculum, but science education has not systematically explored the benefits of learning using active, arts-based approaches (Alrutz, 2004).

The dominance of rationality and the resistance toward integration with other domains, including the arts, permeates much of science education. Science educators who ascribe to the pipeline metaphor (Aikenhead, 2006) argue that integrating science will take the focus off of the soundness of the science ideas (Yoon, 2006). Moreover, tensions over the purpose of science education exist: “[On the] one hand we have authoritative established science knowledge, which is expected to transfer to our students, [on] the other hand we have humanistic aims of science education which is expected to contribute to general liberal education” (p. 3). More recent critical scholarship in science education (Dos Santos, 2009; Morales-Doyle, 2017; Vossoughi & Vakil, 2018) argues that even humanistic goals, as well-intentioned as they are, fall short because they do not necessarily help students develop critical consciousness about the enterprise of science–that science is controlled by powerful and oppressive interests–and the goal should be to increase equity by “transforming [science education] as one part of the unjust societal context in which it occurs” (Morales-Doyle, 2017, p. 1035). Justice-centered pedagogy centers critical knowledge, antiracist teaching, valuing and learning from indigenous knowledges, promoting sustainability, and resisting the false binary (Duncan-Andrade, 2009) in science education, which suggests that rigorous science and a social justice emphasis cannot coexist when, in fact, both classical and sociopolitical learning (Gutstein, 2006) are needed and are central to critical pedagogies. Justice-centered pedagogy is most commonly introduced in middle and high school, which means that for elementary age students, there are scant opportunities to develop sociopolitical understandings and to take action in their communities at the intersection of science and social justice.

How can we leverage using embodied performances, coupled with other multimodal resources, to support science identity work and robust science knowledge while bringing justice-centered pedagogy to the classroom, especially for younger children? Embodied performances in science could provide ways for students to learn science collectively, negotiating between different ideas to come to consensus on how to represent a phenomenon (Aubusson & Fogwill, 2006). "The 'success' of the role play is not that it is entirely accurate, but that it promotes conversation, central to producing, evaluating and modifying the analogy which can help students to clarify and to improve their scientific understanding" (p. 94). However, such an approach is not without challenges. On the one hand, that the performing arts could express science ideas that are inaccurate is a source of debate within science education. On the other hand, arts specialists may argue that the arts should be taught for their own sake, not just to promote understandings in other disciplines. However, a learning environment that obscures disciplinary distinctions between science, arts, and social justice, creates multimodal learning opportunities, and promotes social and embodied construction of ideas, may have the potential to improve students' engagement with and understanding of science.

This instrumental case study will shed light on how fifth graders make sense of science ideas, including disciplinary core ideas, cross-cutting concepts, and science practices (National Research Council, 2012), and sociopolitical understandings, by using their whole bodies as sites of knowledge and identity construction through embodied, multimodal, and aesthetic experiences. Learning, in this study, is understood as both constructing content knowledge, including natural phenomena and sociopolitical understandings, and constructing science identities. Framed from the perspective and aims of justice-centered science pedagogy (Morales-Doyle, 2017) and drawing from sociocultural theories of learning that acknowledge that who students are and are becoming matters in the teaching and learning of science, students are understood as agentic producers who “play their part from within in the world’s transformation of itself” (Ingold, 2011, p. 6). This study will provide a much-needed example of learning environments in which deep understandings of natural science do not get sacrificed when justice and sustainability are positioned as central goals of science education and students are allowed, encouraged, and supported to construct and communicate science ideas in embodied ways.

# II. THEORETICAL FRAMING

## A. Embodiment and its Importance in (Science) Education

Western epistemologies that emerged during the Enlightenment divided human experience such as mind from body and thinking from feeling and positioned the body and emotions as subordinate and in need of control by the rational mind. Descartes (1641/2013) described the mind as separate from the body in the 17th century and dualistic ways of separating the body from learning environments are to this day, still deeply ingrained in educational structures (Wilcox, 2009). For instance, in typical classrooms, for the majority of the school day, students sit in chairs and read and write at desks with the expectation to keep their bodies still. Only at certain times of the school day is embodiment sanctioned, such as recess and gym.

In contrast, embodied theories of learning, rooted in Deweyan constructivism and Freirean critical pedagogy (Nguyen & Larson, 2015) as well as rooted in feminist pedagogies (Grosz, 1993; Luke & Gore, 2014) and embodied cognition (Merleau-Ponty, 1961/2013; Varela et al., 1991), conceptualize bodies as sites of knowledge. Embodied pedagogies embrace the body as central to meaning making and not just in the service of speech or in need of control in the service of rationality (Brickhouse, 2001; Perry & Medina, 2011). Embodied theories of learning offer "alternative models of knowledge production that challenge the interconnected dualisms and hierarchies (mind/body, male/female, white/other), and that recognize the body's capacity to know" (Wilcox, 2009, p. 106).

Furthermore, research on gestures and cognition has provided empirical evidence the body plays an essential role in human cognition (Goldin-Meadow & Beilock, 2010) and that rather than a process that originates in the mind, thinking is grounded in actions and perceptions (Alibali & Nathan, 2012). Concepts are experienced in space and time, with our bodies, so in turn our bodies instinctively represent these ideas (Lakoff, 2008; Lakoff & Johnson, 1980). Spontaneous gestures are used early on in the process of conceptual understanding, which provides more evidence that our bodies are involved in meaning making and help contribute to language development (Roth & Lawless, 2002). Contemporary dance scholarship (Hanna, 2008, 2014) extends findings in embodied cognition in order to argue that dance, a non-verbal language, is "embodied cognition that can convey declarative, procedural, and emotional knowledge, apart from co-occurring with speech" (Hanna, 2008, p. 495), and, for these reasons, it should have a place in education. If conceptual understandings are grounded in the physical environment, and our thoughts and language involve spatial and bodily experience, then we should be asking students to use their bodies in classrooms in order to construct and represent understandings.

In addition to what we know of the body's role from a cognitive perspective, embodied learning also can be understood through the social semiotics perspective. Social semiotics posits that meanings are socially constructed and exist in dialogic relationships in ways that are highly contextual (Bakhtin, 1981). Meanings are made in discourse communities that have particular ways of representing ideas, and these representations cannot be thought of as solely linguistic (Gee, 2000). Building on the theory of social semiotics and expanding Halliday's (1978) framing of language as a social and cultural signifying practice, the multimodal theory of communication argues "meanings are made, distributed, received, interpreted and remade in interpretation through many representational and communicative modes" (Jewitt, 2009, p. 14). Halliday's (1978) metafunctions of linguistic texts–ideational, interpersonal, and textual–also hold for other modes besides language and multimodal texts. Dominant science teaching and learning practices depend most strongly on language but multimodal theory frames language as acting *in ensemble* with other modes, rather than being the central mode of communication (Cope & Kalantzis, 2008; Jewitt, 2009; Kress, 2009; Kress et al., 2001).

Multimodal theory frames meanings as socially mediated within activities and communities (Jaipal, 2010; Kress et al., 2001). Within science classrooms, therefore, meanings are shaped by the practices that are prevalent in the community of the classroom and the communities where learners live outside of school. Kress (2009) noted that cultural practices of any community are deeply intertwined with the meanings developed within semiotic systems / modes used in that community, and shape modal affordances.

> Humans engage with the world and each other through socially made and culturally specific resources, in ways that arise out of their interests. This leads to the well-enough understood problems of *translation*: in one culture, certain cultural domains are well supplied with syntactic and lexical resources, others are poorly supplied; or a domain may be entirely missing in a culture…Areas in the center of social attention are well supplied with semiotic resources; others less so; and what is not attended to in a society is not named or depicted at all. (p. 57)

In the most dominant culture of school science, embodied ways of engaging with science ideas does not receive much attention and in many US classrooms, linguistic participation is most often the only form of participation that is considered appropriate. Such pervasive lack of attention to embodiment as a way of constructing knowledge and identities and communicating in science classrooms prevents students from benefiting from the affordances of activating multimodal semiotic systems of meaning making. Embodied performances can be thought of as "a unique kind of semiotic tool where meaning is expressed and developed simultaneously in visual-spatial-kinesthetic and linguistic modes of communication” (Varelas et al., 2010, p. 304), and a way to position the body as an integral semiotic resource.

However, what constitutes embodied learning is somewhat controversial. Some have argued that current science pedagogies consisting of experimentation and experiential learning with tangible objects and virtual modeling is already *embodied* learning. I take the position, along with others interested in the affective turn in science education (Zembylas, 2016), that embodiment through experimentation and tangible tools is in the service of cognition, rather than treating bodies as sites of knowledge. Science is particularly dominated by rationality, which may make science as a school subject particularly reticent to embrace embodied pedagogies, but in order to engage students in science learning, it is necessary to consider the body’s ways of knowing, and increased attention to sociocultural theories in science education make this a promising time to seek these understandings.

The multimodal theory of communication questions another pervasive duality that plays out in classrooms, that the cognitive and affective domains are separate experiences. Positioning these domains as intertwined, multimodal theory asserts that engaging in various modes to construct and communicate meanings “help[s] us get beyond separations and abstractions such as mind and body, affect and cognition” (Kress, 2009, p. 57). Recently, studies in New Literacies frame body movement and emotionality as texts themselves to be understood as full of meaning, extending theories of multimodality to the affective domain (Leander & Boldt, 2012). In another line of scholarship around movement and emotions, evidence suggests that when viewing body movements alone, others are able to perceive emotions associated with the body movements (Meltzer et al., 2019), suggesting further that movement may be a powerful mode when attempting to infuse science with emotion and affect in the classroom.

In fact, embodied knowledges have a strong cultural component, making embodiment different across cultures and across different cultural enactments. For instance, Medin and Bang (2014) found Native children are more likely to embody their ecosystem while non-Native children are more likely to distance themselves from their ecosystems. They call this a matter of different epistemological orientations. Similarly, students may come to school with different epistemological orientations than their teachers, and their attempts to make sense of and communicate their ideas with their bodies and words may not be recognized as scientific. Additionally, Elmesky and Seiler (2007) who studied African American youth in high school science classes, noted how the students' movement expressiveness while doing science was not welcome by their teachers, which contributed to their feelings of dis-identification with school science. Buttressed by findings in these and many other studies, the present study focuses on embodied learning in enactments of science phenomena in which embodied ways of knowing and being are not only allowed in the classroom but also viewed as robust resources for learning.

Drawing links between multimodal communication and embodied learning theories, and positioning embodied and multimodal meaning making as increasing equity in science education, in this study I examine affordances and constraints of embodied performances for elementary school learners' scientific meaning making and positioning as science people.

## B. **Aesthetic Learning and Emotionality in (Science) Education**

When students make meanings collectively, developing multimodal and embodied representations of ideas and processes, this very act attempts to "concentrate and enlarge an immediate experience" (Dewey, 1934/2005, p. 285) entering into the realm of aesthetic learning. Rooted in Dewey's *Art as Experience* (1934), aesthetic learning positions creativity, imagination, sociality, and emotion as paramount to the learning experience. "Aesthetic learning activates a "complex system of semiotics, responses, and meanings" (Greenwood, 2011, p. 48) and though it may be met with more resistance from the 'rational' discipline of science, the arts may be able to connect us more personally to science precisely because the relationship between human beings and nature "has always been the actuating spirit of art" (Dewey, 1934/2005, p. 352).

Thus far, science education has predominately linked scientific literacy with rational thinking and given little attention to creative empowerment (Kind & Kind, 2007). However, rational thinking and creativity should not be considered as antithetical–rational thinking is also creative, and creativity is also rational. Bridging rationality and creativity supports inclusivity of diverse ways of knowing and experiencing the world. If students are to learn that science is a creative endeavor, however, then they have to actually experience this at school, and through continuous imaginative work in science classrooms, actually become more imaginative about science (Hadzigeorgiou et al., 2012). Creating representations of science phenomena, even when they are not in line with currently accepted science ideas, is useful for creative thinking in science (Kind & Kind, 2007). The fact that both artists and scientists create imagery and analogies in order to make sense of phenomena and imagine being inside phenomena in order to understand it (Warren et al., 2001) points to the "crucial role of imagination in both artistic and scientific creativity" (Hadzigeorgiou et al., p. 604).

Furthermore, through the arts there is the potential for a "personalised relationship and romantic understanding students develop alongside any actual conceptual learning" (Kind & Kind, 2007, p. 25). "[Aesthetic learning] gives us experience, both embodied through our participation and empathetic through exploring another's world…It permits ambiguity, incompleteness, contradiction and complexity, and provides a means to express these without reducing them" (Greenwood, 2011, p. 51). Pugh and Girod (2007) conceptualize a science curriculum in which aesthetic transformative experience is the main outcome of learning. Rather than emphasizing learning from experience, they think of science education as experiencing the world in more meaningful ways through learning science. Like Dewey, they argue that aesthetic learning in the classroom leads to transformative experiences in life. Central to aesthetic learning is the affective domain, often lacking from school science (Girod et al., 2003).

Understanding how affect and emotion co-mingle in the teaching and learning of science has gained significant attention in science education literature (Hargreaves, 2000; Rivera Maulucci, 2013; Zembylas, 2016). In addition, arts-based theories in education (Dewey, 1934; Eisner, 2002; Greene, 1995) have gained enough traction that the arts are widely accepted as important in education, both for their own sake as well as in support of other areas of the curriculum. This could be related to the parallel process of the affective turn that is taking place in education and many other areas of social sciences concurrently, which helps us understand that affect and emotion are not private psychological states, but rather are enacted in social spaces and are relational, involving power and struggle (Estola & Elbaz-Luwisch, 2003; Zembylas, 2007). In science class, emotions and affect are typically considered off-task and distractions rather than resources for learning and agentic participation (Kayumova & Tippins, 2016). "When it comes to managing students' bodies–affect and emotions are often located in a negative and invisible domain–while considering student-motivation, affect and emotions are always wanted and desirable" (p. 573). The affective turn in education has opened up new avenues to understand student motivation and agency as involving the affective domain rather than only being a rational response to one's situation (Athanasiou et al., 2008).

In fact, given the environmental crises that people are facing globally, environmental science and the connection between science and human health is being/should be taught more and more explicitly. Separating the cognitive and affective domains is not conducive to forming a relationship with the environment that is considered necessary for treating the environment and environmental issues with care (Littledyke, 2008). Furthermore, making artificial separations between cognitive and affective domains propagates a view of science in which humans dominate nature by standing back from it, making neutral observations of it, and extracting goods from it, which needs to be "desettled" if children are to develop an intertwined understanding of nature and culture (Bang et al., 2012). Embracing the *affective turn* in education (Zembylas, 2016), with this study I ask how embodied performances act as instantiations of aesthetic experiences in classrooms and how these experiences, which stimulate the affective domain, offer affordances and/or constraints to science knowledge and identity production.

## C. **Drama Pedagogy And Its Role in (Science) Education**

Drama can be conceptualized as an embodied, multimodal, and aesthetic experience. It is a particularly rich and dynamic multimodal ensemble in that it involves language, images, body movement, gestures, sound, and others at the same time and provides both a real and an imaginary environment from which to ground or connect abstract ideas with the physical world through embodiment (Alibali & Nathan, 2012). "Drama education represents an opportunity to involve the body *a priori* in the process of knowing" (Osmond, 2007, p. 1109), which opens up possibilities for more embodied ways of knowing across the curriculum.

Drama practices in the classroom are most often associated with Deweyian constructivism, reflecting real world learning in which we move fluidly between our inner and social worlds, motivated by our feelings and imagination, and take on different perspectives in order to see problems and ideas from multiple points of view (Henry, 2000). Pretending to be something or someone else, the heart of drama, "enable[s] the learner to 'take on the role of another', to cast off an egocentric perspective—and the 'other' can equally be an animate or an inanimate object" (Metcalfe et al., 1984, p. 78, as cited in Dorion, 2009).

In drama two worlds are happening at once, often described in the drama literature as metaxis (Bolton, 1984), in which the physical world and the world of the imagination merge and intersect. The metaxis that happens in drama is useful in science learning because in drama, students can be both in the real world and in the make-believe world, concurrently, as they explore abstract science entities and processes and become 'insiders' as they explore science from within the process itself (Varelas et al., 2010).

In *embodied performances,* students are invited to move and configure their hands, arms, and whole bodies to take up entities, for example, wind, water molecules, acid rain, or blood pumping through the heart. These processes may be either invisible to the human eye or so much a part of the everyday that they may be outside children's awareness, and so acting them out can provide analogous ways of thinking and mental images, which is something that scientists do to "play with ideas" (Hadzigeorgiou, 2012, p. 605). Then, through reflecting on these enactments[1] as a group, children can construct socially mediated science understandings that become more personally meaningful (Butler, 1989; Hendrix et al., 2012). The drama becomes both an aesthetic event (Girod et al., 2003; Hadzigeorgiou et al., 2012) and an embodied, and imperfect, science

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[1] enactments refer to embodied performances

model (Aubusson & Fogwill, 2006) that can be reflexively analyzed and revised by the class in order to come to collective understandings about science phenomena (Odegaard, 2003). Dramatizing mediates students' learning and students' own everyday knowledge mediates their dramatizing (Varelas et al., 2010). These everyday knowledges can be brought into how students act out science concepts, using their everyday experiences and their imagination to represent science processes, thus, enacting culturally relevant pedagogies (Ladson-Billings, 1995).

Teachers are called on to "seek out ways in which [they] can promote cultural hybridity and bricolage where science understandings are constructed and represented using these expressive dispositions" (Elmesky & Seiler, 2007, p. 79). However, teachers may not be willing to incorporate active, dramatic role play in their science classrooms, for many legitimate reasons. First, for drama to work in classrooms, teachers need to spend time creating a community of learners willing to take risks together (Butler, 1989). There may be a reluctance to use embodied and dramatic pedagogies because of a perceived loss of control of the students and the teachers' and administrators' limited degree of comfort with 'messiness' in the classroom and non-authoritarian expectations (Alrutz, 2004). In other words, a willingness to desettle the normalized expectation for a teacher's high status and control over students is needed along with a "shared frame of trust, safety, collaboration, respect, and democracy" (Edmiston, 2003, p. 5). Although performance has been used successfully to engage people in social and political struggles as well as in powerful movements in literacy, such as Augusto Boal's *Theatre of the Oppressed* methods (Boal, 1974), educators in normalized school settings may be resistant to performance in their own classrooms (Wilcox, 2009) due to schooling practices that favor social control as a means to manage children's bodies and especially bodies of students who have endured racist and colonial treatments based on perceptions of their bodies as dangerous to those in power (Carter et al., 2017; Hines-Datiri & Carter, 2020). There is a perceived clash between bodies and schooling: “to work with bodies is to invite the liberatory–and risky–potential of messy, physical specificity into the orderly conceptual hallways of institutionalized schooling” (Osmond, 2007, p. 1117). Cordileone (2011) noted:

> There are an incredible number of practical benefits to inclusion of artistic exploration in the core curriculum…But despite clear and traceable evidence of the benefits inherent in this pedagogy, it remains a very dangerous model, as it threatens to upend the typically heteronormative, sovereign institutions that patrol the distribution of knowledge. (p. 56)

Thus, drama, in which bodies become activated, may be chosen less often than other arts that lend themselves more independent work, such as drawing. However, elementary teachers know that prolonged periods of sitting are not conducive to active learning. Drama, dance, and movement in elementary learning environments are already used broadly, and it is plausible that drama in science classes exists but it is understudied in the science education research literature (Dorion, 2009). Whether or not this is the case, we know that in order to motivate more students in science, we have to expand our teaching repertoire in schools to include creative, active approaches to learning (Braund, 2015).

Second, even teachers who are excited by the thought of using drama to teach science, may not try it if they do not have any background in drama. However, it is not necessary for teachers to have such a background as their main contribution could be to carve out the time for children to create embodied performances and to facilitate reflections afterwards, in which students can negotiate meanings that unfolded (Odegaard, 2003) and share emotional responses in order to gain the full learning potential inherent in using drama in science (McSharry & Jones, 2000).

Scholars who have studied the use of drama in science contexts specifically (Andersen, 2004; Bailey & Watson, 1998; Braund, 1999; Butler, 1989; Dorion, 2009; Fels & Meyer, 1997; Kambouri & Michaelides, 2014; Littledyke, 2004; Overton & Chatzichristodoulou, 2010; Varelas et al., 2010; Wilcox, 2009) argue that drama–an artistic process that requires the synthesis of body, mind, movement, voice, and character–may help shorten the distance between children's everyday worlds and the world of science, thus showing how drama can lead to the creation of hybrid spaces for science learning that may be beneficial for students of color (Calabrese Barton & Tan, 2009).

Furthermore, drama pedagogies are known to support children's exploration of power, regardless of subject matter, and increase collective agency. Nelson (2011) wrote:

> In the safety and community of the drama situation, students have time to strategize, consider options, and experiment with solutions…Most important students can begin to see themselves as agents of change as they develop inquiry, analysis, and negotiation skills that are the foundations of social action. (p. 83)

In this way, drama pedagogy in science classrooms could become a tool for "rightful presence" (Calabrese Barton & Tan, 2019, 2020), an equity framework that "focuses on the processes of reauthoring rights towards *making present* the lives of those made missing by the systemic injustices inherent in schooling and the disciplines" (Calabrese Barton & Tan, 2020, p. 4). In a way, embodied performances promote equity by "help[ing] students to challenge and transform what participation in the disciplines entails or what meaningful representations of learning look like" (p. 4).

In the present study, I theorize that embodied performances, as an example of drama pedagogy, can elicit personal and authentic ideas about science and help students understand that science knowledge is intertwined with their world (Butler, 1989) and may be an opportune way for students and teachers, dialogically, to construct scientific knowledge and communicate science ideas in creative and joyful ways (Edmiston, 2003). Embodied performances also have the potential to disrupt the common teacher-dominated, learning-as-transmission environment of science classrooms and bring school science closer to the creative and imaginative aspects of science itself (Odegaard, 2003). Finally, embodied performances have the potential for creating equitable science instruction, as they invite children to develop and express ideas with their whole selves, which in turn allows more expansive opportunities to develop and express understandings. In this study, I ask how embodied performances, informed by theory and practice in drama pedagogy, offer affordances and/or constraints to engaging in and learning science.

## D. Identity Construction as Part of (Science) Learning

Mead and the symbolic interactionists understood the self only through social interaction and "negotiated meanings" (Stets & Burke, 2003, p. 10). Through communication, both bodily and linguistic, meanings are made, and significant symbols are exchanged. Identity theory, which has grown out of the symbolic interactionist tradition, aims to understand the roles people take up in various contexts. It deals with "individuals' role-related behaviors," differently from social identity theory that is concerned with "group processes and intergroup relations" (Hogg et al., 1995, p. 255). Theories of identity construction, both identity theory and social identity theory, have taken a central position in urban science education literature, as emphasis on sociological and anthropological concepts has been proven useful in transforming science education (Varelas et al., 2012). Identity construction is now a major consideration in "ambitious science teaching" (Windschitl & Calabrese Barton, 2016) because substantial research has accumulated that has shown how "learners' culturally situated experiences, ways of communicating, modes of sense making, and perceptions of self as knowers" result in science engagement and learning (p. 1116). If we want to understand learning in science contexts, then we must recognize that identity construction is *evidence* of learning (Varelas et al., 2012) as shifts in knowledge *and* identity tell us that people have undergone a process of learning, as in "a change in knowledge, skills, dispositions, efficacy, and habits of mind" (p. 324).

People take on roles depending on the particular sociocultural groups in which they participate and the norms, rules, and habits that govern participation in each group. In a classroom, and specifically a science classroom, children enact various roles that are available and allowed or not, and to various degrees. Each classroom is a "figured world" (Holland, et al., 1998) with its own "coproduction of activities, discourses, performances, and artifacts" (p. 51). Looking closely at micro-level identity work in classrooms, it is important to think of identity work as constrained or enabled by various structures (Calabrese Barton et al., 2013; Varelas et al., 2015). We have to ask: "Who are students obligated to be?" (Carlone, 2012, p. 12). Who students are and are becoming in science classrooms is influenced by various structures (e.g., cultural, social, physical, symbolic, linguistic, political structures) at various levels (i.e., micro, meso, and macro), which shape what counts as being scientific. When competence in, and performance of, science becomes inextricably linked with artistic processes of whole-body movement, drama, and 3-dimensional, dynamic, embodied modeling of scientific phenomena, a certain kind of cultural production happens that makes certain identities available and beneficial, ones which may not be available in other science learning environments.

Even when identities are made available, role-related actions are influenced by "identity hierarchies" (Hogg et al., 1995). Higher recognition of certain roles propels these role-related identities to a higher status and, thus, a higher possibility that people will continue to take on such roles. The more recognition one experiences from others while acting in a certain role, the more "identity salience" gets associated with that particular role (Stryker & Burke, 2000). Moreover, Nasir and Cooks (2009), in their study of track and field identity construction, found that the more social connections the students experienced within the practice–both with their coaches and with one another, which they call "relational resources" (p. 48)–the stronger their connection became to the practice of track itself and the more salience their track identity gained. Identities with more salience offer people more "identity capital" (Côté & Levine, 2002) that they gain over time as they successfully perform role-related actions.

Furthermore, identities are constructed as people participate in activities within particular groups and communities, but also as they tell themselves and others who they are and who they are becoming by recounting and interpreting experiences. Thus, the stories people tell about themselves are their identities in many ways. Kane (2012) found that the focal student, Kenny, had a few enduring "identity markers" that spanned his multiple identities, and that "by interweaving these identity markers across three 'as if' worlds, he integrated his rich inner life, his family experiences and expectations, and his love of science into a science self" (p. 30). Kane's findings are instrumental in understanding that children construct science identities at the intersections of performed and narrated identities.

Another source of identity salience lies in whether roles associated with a particular identity align or are in conflict with other salient roles. Varelas et al. (2012) emphasize learning science and mathematics as *racialized* experiences. Students' racial identities are inextricably related to identities they develop in classrooms of any subject matter, including science. Who students are, for instance, African American / Black, Asian, or Latinx, and who others see them being as African American / Black, Asian, or Latinx peoples *in science spaces*, shape their science identities. Teachers should "shape opportunities for humanizing participation by valuing students as cultural and whole people, whose knowledge/wisdom, experiences, and fraught histories are integral to disciplinary learning" (Calabrese Barton & Tan, 2020). Science classrooms, in particular, can be powerful learning environments when they become "third spaces" (Moje et al., 2004), hybrid places which children construct as they bring together with science ideas their everyday understandings and ways of being, and where other salient identities, racial, ethnic, linguistic, gender, sexuality, or other out-of-school identities are valued rather than ignored, devalued, or positioned as at odds with science identities. Because it invites children to bring in what they know and value, and their racial, ethnic, gender, sexuality, linguistic, and other identities intertwined with their whole bodies, drama allows for integrating other identities with science identities, making science classrooms that use drama an example of third spaces.

Latinx elementary children's interests in science can be "uncovered, celebrated, and further nurtured" (Varelas et al., 2014, p. 1251), in third spaces, in which children combine their lived worlds and their school worlds, and in which curricula and classroom practices are designed according to asset-based pedagogies in which their whole selves are valued and recognized (López, 2016). Building on Varelas et al.'s (2014) claim that dialogic listening between teacher and children is an example of the types of caring advocated specifically for Mexican American students by Valenzuela (1999), I extend this to embodied performances because so much of the work is centered around dialogism and collective sense making, in essence, listening to and valuing children's ways of thinking.

DeJarnette (2012) notes that engagement with science curricula is particularly lacking in the elementary grades even with calls for more instructional time devoted to science. Yet, elementary years are a critical period for developing Latinx children's interest in science by engaging children as participants in their own holistic learning (Gautreau et al., 2019). Drama in science could be a promising way to provide these types of engaging science experiences that spark children's interest in science during this critical period. For learners who are emerging bilinguals, such as the students in Bernal's (2007) study, albeit that these were high school students, the use of drama, as they reported helped them with their second language learning. Scholarship in *translanguaging*, in which students from different linguistic and historical backgrounds communicate with "a collection of linguistic and non-linguistic resources, without regard for socially and politically constructed discursive systems" (Suarez, 2020, p. 2) also provides fruitful linkages with drama and multimodal pedagogies in support of emerging bilingual students.

Counting embodied, multimodal practices as science practices in elementary school may allow for hybrid spaces in which expanded roles as science learners are made available and possible. Embodiment practices in education provide affordances for learning, but we need to know more about what happens when we purposefully and systematically broaden the available scientific roles that young children can take up. How do the new identities, made available in contexts in which arts and science co-mingle, get recognized as competent science performances? How do identity construction and content knowledge shape each other when children enact embodied performances of science? How do students construct science identities when engaged in embodied performances in science and how may these performances expand students' notions of being scientific, to include being expressive, using movement, using imagination, and performing?

In the present study, I theorize that planning, performing, and reflecting on embodied performances may allow for opportunities for productive identity work. Teacher and students, co-constructing knowledge at the crossroads of artistic and scientific epistemologies, could create expansive notions of what it means to perform science, and their growing competence in science could then become more visible. In turn, they could be recognized by each other and their communities for being science people in more expansive ways than usually found in science contexts. In other words, when these ways of learning become normative practices in a science classroom, students historically marginalized and minoritized in science settings could perform science, be seen as competent in science, and get recognized as science people–all elements essential for identity construction (Carlone & Johnson, 2007).

## E. **Social Justice and (Science) Education**

Gloria Ladson-Billings (1995) proposed culturally relevant pedagogy (CRP) as a theory to describe the practices of "successful teachers of African American students" (p. 162) through the central tenets of "academic success," "cultural competence," and "critical consciousness" (p. 160). Students' academic success in "literacy, numeracy, technological, social, and political skills" (p. 160) is essential for participating actively in a democracy. Teachers also need cultural competence, considering students' culture as a "vehicle for learning" (p. 160) instead of in conflict with the school culture and therefore unwelcome in the classroom. A teacher who allows students to use their home language in the classroom or who invites parents into the classroom to share cultural knowledge with the students are examples of culturally competent teachers. Then, there is the need for critical consciousness, rooted in both Paulo Freire's (1970) critical pedagogy and the empowering pedagogy of the Mississippi Freedom Schools (Hale, 2016) established during the Civil Right Movement and intended to liberate African Americans from oppression through education. Achieving academic success and cultural competence along with being able to "critique the cultural norms, values, mores, and institutions that produce and maintain social inequities" (p. 162) are CRP's pillars, or competencies, that teachers need to nurture in their students. CRP is considered a transformative pedagogy, because its purpose is to transform the world's racial inequities and colonizing practices through education and to break the cycle of social reproduction of oppressive realities of those whose lives and well-being have been ignored.

Freire's and Ladson-Billings' call for the development of sociopolitical understandings were foregrounded in science education with Dos Santos's (2009) call for science education to be understood as explicitly having a "sociopolitical function" (p. 362). Teaching science through socio-scientific issues (SSI) was not new, and although it had its critics, science has been taught through connections to social issues in order to increase its appeal to students and its inclusiveness of other values than those of the white middle class. Recognizing Aikenhead's (2006) urging for humanistic goals for teaching science, Dos Santos argued that in order to enact Freire's critical pedagogy in science, what was needed was "a more radical view to humanistic science education through the perspective of an education that may change the inequitable social reality of the globalized world" (p. 362).

Focusing specifically on African American students, Mutegi (2011) argued that Western science should be taught in schools so that it is understood as “the best product of the intellectual culture of those responsible for [African Americans’] colonization” (p. 306). Echoing Ladson-Billings, Mutegi considered that learning science is beneficial to colonized people, but learning about the natural world and how to use that knowledge to make sound decisions and participate economically would not alone transform the injustices imposed on African Americans (p. 306). For that to happen, critical consciousness was needed in science education in order to change the world’s inequitable social structures.

Critical consciousness and taking action against inequities are both necessary for justice-centered science pedagogy–JCSP (Morales-Doyle, 2017). JCSP is a framework built out of the traditions of the socially transformative pedagogies of Ladson Billings and Paulo Freire, which positions young peoples’ agentic social action, stemming from, and contributing to, critical consciousness, as the pedagogical goal. Science curriculum in JCSP centers around issues of environmental racism and positions science as a powerful tool that has to be mastered and, at the same time transformed, in order to take action toward repairing injustices that low-income communities of color disproportionately endure. Morales-Doyle argues that science should be a tool for not only learning about these issues, including developing scientific knowledge and understanding how these issues disproportionally affect minoritized people and communities, but most importantly, to position young people as “transformative intellectuals” (p. 1037) who specifically engage with local, indigenous knowledges as they work to tackle issues of equity and sustainability in action research projects (p. 1038). In addition to becoming critically conscious, the students and teachers who embrace JCSP learn through taking action, and in so doing, developing critical science agency (Basu et al., 2008). Becoming scientifically literate, according to these critical pedagogical stances, necessitates not only the learning of science content, which, similarly to Ladson-Billings, must happen and to a high degree, but also the development of agentic identities and practices that empower people to take action to improve inequitable environmental conditions (Schenkel et al., 2019).

In the present study, I theorize that embodied performances can both be an equitable, transformative teaching practice in the classroom, while at the same time, offer affordances to children who are grappling with issues of justice in their own communities and in the world. The science learning context can be understood not as a neutral place of learning, but rather a space in which sociohistorical forces make it a "site of contestation" (Philip & Azevedo, 2017, p. 530) that either would reproduce the status quo or transform it. The class in this study explores the Flint, MI crisis and the lead poisoning of low-income communities of color as part of its year-long water curriculum. This offers an example of justice-centered science pedagogy, where the scientific understanding of the process by which lead gets into drinking water sources and then affects the human body develops alongside critical consciousness and sociopolitical understandings of how this crisis grew out of conditions of environmental and institutional racism as well as injustices that burden low income communities in disproportionate ways.

# III. RESEARCH GOALS

We know that people in general, and in particular children, learn and communicate in multimodal ways, but how children use their bodies to construct and express science ideas is a relatively unexplored area. Especially lacking in the literature are studies of how elementary school students develop and express science ideas in embodied and other multimodal ways. This study aimed at addressing this gap in the literature and extending the existing knowledge on the multimodal, embodied nature of communication, and its affordances and challenges, in science classrooms. The analysis of multimodal communication at the micro-level along with the analysis of artifacts created aimed at contributing to understanding how children make meaningful semiotic choices relative to science ideas. By asking what students are thinking and making space for them to create embodied performances of science ideas and reflect on these, the goal was to create an opportunity that centers heterogeneity and disrupts homogeneous ways of doing and communicating science.

The study aims at making visible children's sense making of science ideas using their bodies, ways that should not be ignored or viewed as unscientific. Multimodal analysis affords ways to address skepticism of arts integration in science, heard in the common question, "but where is the science?" It is there, but we have to take the time to make sense of what students are communicating and ask them about their semiotic choices, and engage them in analyzing these choices themselves, aiming at shedding light on how these choices map onto classical and sociopolitical knowledge of science.

Moreover, existing scholarship includes examples of how justice-centered pedagogy is enacted in middle and high school classrooms. Younger students are not often given the chance or the responsibility to engage in and learn justice-centered science. It may be thought that the issues can bring up too many emotions for young people to handle. However, emotionality in science, and an emotional connection to the environment and to communities that experience environmental racism, may be needed for learning science in deep ways–ways that are connected to both the physical and social world. The goal of this study was to add to our understanding of curricular choices over time that contribute to critical consciousness and exploration of the sociopolitical aspects of science, and how young students take up these ideas when afforded opportunities to use their whole selves in developing, communicating, and negotiating science meanings and identities.

Studies in science education mostly focus either on content knowledge *or* on identity construction but with this study I aimed at describing and interpreting both, adding to the sociocultural science education literature that considers learning and identity construction as intertwined processes. In referencing findings from Martin's (2006) study using interviews with African American adults in order to learn retrospectively about their identity construction at earlier ages, Varelas et al. (2012) suggest that we need to advance our empirical understandings of identity construction during the early years. There is still limited knowledge about how science identities become "science trajectories" (Johnson, 2012) over time. These science trajectories may result from the various material, relational, and ideational resources (Nasir & Cooks, 2009) and experiences that people have, which add identity capital and accumulate over time to become critical parts of their actual identities (Sfard & Prusak, 2005). However, most studies of science identity focus on the middle school and high school years. If we want to know how science trajectories happen over time, we need to reach back further in the development of these identities, into the elementary years. Science identity research with young students of color (Carlone, 2012; Kane, 2012; Varelas et al., 2014) has shown that salient meanings about science are constructed at these younger ages and they need attention, especially considering trajectories as happening over the whole schooling period. It is promising that identity construction has been considered as a central component of ambitious teaching practices (Windschitl & Calabrese Barton, 2016) which will hopefully encourage more science identity research in the younger grades.

In science education research, Kane's (2012) findings also point to the need for asking about the lived experiences of children from their own perspectives, who, in her study were African American. Her research methods, her consistent presence in the classroom and conversations with individual children about their life experiences outside of the science classroom, provided for so much richness and depth: "First-hand accounts of their lives and experiences can uncover the rich and complex ways in which African American children make connections with school and science as well as the resources they bring to school to do so" (p. 40). Extending these ideas to Latinx students, this study aimed at adding to the research that focuses on young Latinx students' rich resources and interests in science, in order to provide a counter-narrative to deficit-focused viewpoints that are frequent in educational research and practice related to students of color.

Science is known to be a gateway discipline (Aikenhead, 2006) with many institutionalized obstacles facing students of various historically marginalized groups reflected in the disparities in participation in science of African American and Latinx students. Structure and agency influence one another such that "social structures outside given social networks act as boundaries affecting the probability that persons will enter those networks" (Stryker & Burke, 2000, p. 285). The goal of this study was to make visible how a small community of Latinx learners develop their agency in their science class, which provided them with structures that break down such boundaries, contributing to robust learning and long-term positive science identity trajectories (Johnson, 2012).

Although we know important aspects of the interrelatedness of identity construction and content learning (Varelas et al., 2012) and about the power of multimodal learning in science to elicit engagement and powerful ideas from young children (Varelas & Pappas, 2013) the existing scholarship lacks examples of how the construction of science understandings and positive science identities may unfold when science ideas, embodied ways of knowing, multimodal communication, emotionality, and justice- and sustainability-centered teaching become intertwined.

Furthermore, theoretical arguments are made for the need for inclusion of arts-based learning in science, but limited empirical evidence exists that describes how children actually learn science in these ways. This study was designed to provide a year-long example of elementary school students engaging in science learning, that becomes progressively more justice-centered as the curriculum unfolds, using creative drama and other multimodal communication. Providing empirical evidence related to the construction of knowledge in science and the preforming arts will encourage more exploration of their synergies and trouble the division between arts and sciences prevalent in schools and in society. By illuminating the use of arts-based practices in science, this study aimed at contributing to expanding students', communities', and researchers' conceptions of science beyond a predominantly rational, cognitive, and linguistic practice.

If we are to realize justice-centered aims of science education, as well as broaden the appeal of, and the scope of what counts as science, we cannot remain wedded to the current pedagogical practices. "In science, as in other fields, overturning dysfunctional, counterproductive practices must commence with cultivation of a progressive, inclusive culture that does not value any one form of knowledge, or knowledge expression, over others" (Schmidt, 2011, p. 441). By specifically drawing links between science and the performing arts, two disciplines often pushed to the margins within urban elementary education, my hope has been to bring more attention to each of them as well as to point to fruitful linkages between them. This could encourage more educators and researchers to explore using drama, dance, and movement to teach science, as well as more exploration of science ideas in arts contexts, such as in the performing and visual arts. By drawing out these connections and building on current thought on arts integration in schools (Hardiman, 2018), I hope to inspire collaborations between the arts and sciences and increase the opportunities for children to learn science multimodally and in embodied ways.

Learning science is both constructing disciplinary knowledge and constructing the self in relation to the discipline (Brickhouse et al., 2000; Olitsky, 2006; Varelas et al., 2012) as one is positioning oneself and is being positioned by others as a doer of that discipline over time. The goal of this study was to illuminate what identity construction looks like in a particular figured world in which students practice scientific thinking and communicating through the multimodal texts of embodied performances. I started with asking "*what is going on here?*" (Warren et al., 2001) in terms of both what learning is happening and who the students are becoming. The research question I asked was: How is science learning, defined as both constructing science knowledge and constructing science identities, shaped by student engagement in embodied performances of science ideas, and in what ways is participating in embodied performances of science ideas shaped by science learning.

# IV. METHODS

With this study I sought to uncover how complex social processes unfolded and how people interacted within them, bringing forth multiple viewpoints and experiences (Creswell & Poth, 2018), influenced by sociocultural and sociohistorical forces. The study was framed by bringing together distinct but compatible theoretical frameworks: embodied, multimodal, and aesthetic learning, identity construction, and justice-centered science pedagogy. Qualitative data collected in one classroom over the course of a school year were analyzed to understand how students took part in, and made sense of, embodied experiences in their science class. Through an instrumental case study (Stake, 1995), I explored the research question related to how learning and identity construction happened in this particular context within the bounded case (Baxter & Jack, 2008) of a fifth grade class using an integrated science curriculum. In order to shed light on how embodied performances, which included a range of body movements from gesturing to whole-body movement, and were part of this science class, shaped knowledge and identity construction over the course of the year, the study included an analytical focus of the experiences of five focal students. Other students' contributions provided important windows for analysis as well, but these five students' experiences provided a central focus. Video and artifact analysis shed light on knowledge and identity construction as it unfolded over time. Multimodal discourse analysis was also used in order to analyze the micro-level of semiotic choices for exploring, representing, and communicating science ideas, including gesture, gaze, body movement and position, and verbal language. Additionally, The Laban/Bartenieff Movement System (LBMS)[2] (Fernandes, 2014; Studd & Cox, 2019) was used to analyze the children's movements through

[2] Laban Movement Analysis (LMA) and Laban/Bartenieff Movement System (LBMS) are the same, but the latter is used to recognize Irmgard Bartenieff's contributions to this analytical system (Tsachor & Shafir, 2019, p. 3).

"Body," "Effort," "Space," and "Shape,"[3] which further shed light on their meaning making and identity construction.

## A. **Research Design**

This study used a case study methodology (Yin, 1994) because case studies can lead to rich, context-dependent knowledge (Flyvbjerg, 2011). "According to Yin (1994) the case study design must have five components: the research question(s), its propositions, its unit(s) of analysis, a determination of how the data are linked to the propositions, and criteria to interpret findings" (Zucker, 2009). The propositions captured both theoretical underpinnings and my personal experience of the issues in various contexts, which, taken together, motivated the study.

More specifically, this study was an instrumental case study (Baxter & Jack, 2008), aiming to understand the phenomenon of embodied science learning within a particular context: Ms. Rosario's science class that was focusing on an integrated water curriculum. The context of this particular classroom was crucial to understanding how the phenomenon of embodiment played a role in learning, but the focus of the study was on the *phenomenon in context* rather than the context itself. Within the bounds of this class, the students' particular knowledge and identity construction manifestations while participating in embodied performances were analyzed and synthesized.

Moreover, although the contributions of five focal students were particularly captured and analyzed, all students' contributions provided the evidence that led to the themes that emerged, and examples from various students and groups of students are used to illustrate that evidence. Thus, the focal students in this study were not considered as embedded cases within

[3] In movement analysis, LBMS movement vocabulary terms are capitalized.

the larger case of the class as the class, including the students, teacher, and the curriculum were not the focus of the study. Rather, the ways in which they interacted with each other in dialectical ways and in relation to embodied performances constituted the core of this study. The students' individual and collective science thinking and identity construction were explored to understand the form and functions of embodiment in the classroom over the course of the year-long science curriculum. A time-series analysis (Yin, 2011) attending to the chronology of the embodied performances mapped onto student knowledge and identity construction led to the development of the study themes.

## B. Participants in Ms. Rosario's Class

There were 30 students in Ms. Rosario's self-contained fifth grade class during the data collection year. Approximately 70% of the students in that class were fluent bilingual Spanish-English speakers and readers and 30% were emerging bilingual speakers and readers. Ms. Rosario described approximately 90% of the class as second-generation Americans of Mexican descent and roughly 5% of the class as first-generation of Ecuadorian descent. Two students in the class were born in Mexico and crossed the border, one during the data collection school year and one a few years prior.

Ms. Rosario's classroom was in a public school in a large Midwestern city neighborhood, with mostly Latinx students (96%) living in households experiencing economic distress (92%). The school, Sylvia Mendez[4] Academy, is a mathematics and science magnet public school in the large city district. A systematic look at the science curriculum had not ever been undertaken since the inception of the school. Mathematics and literacy received the most emphasis, while

[4] The name of the school is a pseudonym. It was chosen because Sylvia Mendez, a nurse and civil rights advocate for Latinx Americans, did similar work in health and advocacy to the person for whom the school is named after.

science instruction had been pushed to the margins (not uncommon in US elementary schools that serve predominantly students of color, but perhaps surprising for a math and science magnet school), leaving the decision to teach science mostly up to each teacher or team of teachers at each grade level. Teachers in the school had access to FOSS (Full Option Science System) kits and each teacher or team of teachers decided how they would use them. Ms. Rosario engaged in bilingual instruction, which was her decision rather than mandated by the school administration. Ms. Rosario felt it was important for her students in their last year of elementary school to experience bilingual instruction, especially for the students whom she described as emerging bilinguals, as middle school made no such promises. Often Ms. Rosario spoke first in English, but then translated in Spanish orally or in writing on the board. She often discussed concepts in Spanish and English interchangeably and wrote science vocabulary in both English and Spanish. She gave her students a choice to write in English or Spanish on most assignments and when students spoke in English in class, often Ms. Rosario asked them to then state their ideas again in Spanish.

## C. <u>**The Integrated Science Curriculum**</u>

Ms. Rosario, who identifies as an Afro Caribbean female of Puerto Rican descent, was a veteran teacher who had taught fourth and fifth grades over the ten years teaching at that school. She was also a member of a partnership between school- and university-based educators designing and studying embodied performances in elementary and middle school science classrooms. The university-based educators were researchers at a large, public, research university in the same city studying science, language and literacies, and theater. Ms. Rosario joined this group of teachers and researchers because of prior productive collaborations with researchers at this university and because of her enthusiasm for teaching science and desire to make science a focus in her classroom. Unlike previous years, when she taught science as a separate subject, during the data collection year she wanted to look for ways to integrate science and other areas of the curriculum and explicitly teach her students about socio-scientific and justice-focused issues, such as water pollution and its effects on the human body. She decided that her personal commitment to using science to understand social justice issues would be reflected in her teaching. About five years prior to the data collection year, Ms. Rosario had participated in a research project in which she was able to bring science and issues facing the community together in her teaching. She then traveled to Puerto Rico to visit family and one of her uncles there expressed grave concern for the fair distribution of water. These conversations with her uncle spurred her own passion for the study of water and how water intersects with social justice. She vowed to make sure that her students would study water in interconnected ways from that point forward. During the data collection year, she decided for the first time to do a year-long curriculum focused on the study of water, integrated with other areas of the curriculum (Table I).

Ms. Rosario developed this curriculum iteratively over the school year, propelled by her own research and with the help of the other members of the partnership. Ms. Rosario intentionally wove the study of water through reading, writing, social studies, and of course, science. For instance, in order to introduce themes of water scarcity, she assigned a book called *A Long Walk To Water* by Linda Sue Park. The book centered around two parallel stories in Sudan, one about Nya and her twice daily walks to a lake to get water for her family, and another about Salva, one of the “lost boys” of Sudan in the 1980s, and his journey  across Sudan in search of a place to live. Along with character analyses and book discussions as

**TABLE I**
INTEGRATED SCIENCE CURRICULUM OVER THE COURSE OF THE SCHOOL YEAR

| Month | Topics | Key Ideas | Multimodal Learning Activities |
|---|---|---|---|
| **October** | Water Cycle | Water cycles through different states of matter in the atmosphere | Read informational books and articles<br><br>Made posters of water cycle in groups<br><br>Created embodied performances of the water cycle in small groups, that included movements to represent collection, evaporation, condensation, and precipitation |
| | States of Matter | Water molecules behave differently in solid, liquid, and gaseous states | Watched animated videos and simulations<br><br>Created an embodied representation of a glass of water that starts to boil, in which students represent water molecules |
| **November** | Water Cycle (Continued) | | Read *A Long Walk to Water* by Linda Sue Park<br><br>Created more complex enactments of water cycle representing more science concepts and processes |
| | Permeability of earth materials | Sand, soil, clay, and gravel allow for different levels of permeability of water | Observed over several days water poured into cups with different earth materials |
| **December** | Groundwater and Aquifers | Water is filtered and stored within aquifers underground in confined or unconfined aquifers | Drew diagrams of aquifers in groups<br><br>Built models of aquifers |

| | | | |
|---|---|---|---|
| | | Water pumped from aquifers is a source of drinking water | Created embodied performances of confined and unconfined aquifers |
| **January** | Flint, MI water crisis | Drinking water in Flint, MI became contaminated with lead, which specifically affected economically stressed communities of color | Read various print articles<br><br>Watched Nova special on Flint, *Poisoned Water*<br><br>Participated in Socratic Seminar using articles read to provide evidence |
| **February** | Lead contamination- micro level | Lead pipes in Flint were corroded by high levels of chlorine and lack of anti-corrosive protection | Created performances of the Flint, MI water crisis from different perspectives (i.e., government, inside the pipes, a family's home, a protest) |
| **April** | Inventions- Engineering solutions to pollution | People have agency to address pollution problems by designing solutions | Designed prototypes of inventions that would target and alleviate health problems caused by pollution<br><br>Created embodied performances of human body systems (i.e., respiratory, digestive) |
| **May** | Human Body Systems and Impact of Water contaminated with Lead on Health | Lead affects different body systems in adverse ways | Created embodied performances of how lead damages different human body systems<br><br>Measured water quality of water from different fountains within school building<br><br>Studied data released in 2016 in city's school report on lead concentrations in school fountains |

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|---|---|
| | Wrote letters to allies to inform them of the dangers of lead in school drinking water fountains and propose solutions<br><br>Saw sixth graders from another school perform a play they had composed on water, air, and land pollution<br><br>Prepared multimodal presentation for lawyers at local university (ABC project) |

part of reading instruction, Ms. Rosario's class explored evaporation and properties of soil, sand, and clay through science investigations because these processes were mentioned in the book as Nya searched for alternate sources of water after the lake near her village dried up.

Studying the water cycle followed, and when it came to water collection concepts, water pollution, specifically related to lead, and the sociopolitical realities that influence access to lead-free water were ideas Ms. Rosario was determined to explore together with her students. Ms. Rosario pulled in different resources related mainly to Flint, MI but she also brought in articles and videos about drinking water pollution struggles in cities like Detroit, Washington, DC, and the city where her school resided. As her students learned more about how lead affects the body while at the same time exploring a FOSS unit on human body systems, they became more and more cognizant of the sociopolitical underpinnings of the water pollution crisis in Flint and were able to express their "moral outrage" (Duncan-Andrade, 2009) in increasingly agentic ways, culminating in a presentation on lead pollution to law students and lawyers who worked for the city at another local university's school outreach event called the ABC Project.

Throughout the year, Ms. Rosario remained committed to one of the central goals of the school-university partnership she was participating in, namely, using embodiment to support students' science learning. Ms. Rosario embedded embodied practices into her teaching that the school-university partners developed together, from asking students to represent science ideas individually with their hands or their whole bodies to asking them to create embodied performances in groups anytime they were learning about new science ideas. The students in Ms. Rosario's class explored in this way the states of matter, the water cycle, aquifers, the Flint, MI water crisis, human body systems, the process in which lead gets into drinking water, and how human body systems are damaged by lead poisoning. In addition, Ms. Rosario's students engaged in other multimodal projects throughout the year including visual designs of the water cycle, scientific posters, diagrams and small-scale physical models of aquifers, and a class slide show presentation on lead for the ABC project.

## D. <u>**The Five Focal Students**</u>

Five students were selected as focal students. They were chosen after the data collection year had ended, mostly based on their ample participation in class and the relatively even distribution of available data that included their contributions over the course of the school year. All of the focal students were second generation Mexican Americans and ten and eleven years of age. The profiles below were developed based on conversations I had with Ms. Rosario about each of the students after the school year had ended.

**Dante** lived with his mother and father. Ms. Rosario described Dante's writing as lagging behind his peers, so much that it was difficult to follow it. Dante was sensitive about his writing and often chose to contribute to group projects by planning aloud rather than writing anything down. During science, Dante was one of the most outspoken members of the class, and during group work on enactments or posters, he was a vocal member of the group, often working out how to explain concepts to his groupmates and to develop a more thorough understanding of ideas when Ms. Rosario would check in with groups to determine how they were doing. Toward the beginning of the year, Ms. Rosario described Dante as more socially "immature" than his classmates. But, as she witnessed his development and learning over the course of the year, she commented that he had a "fantastic year of growth." She said that she made a point of complimenting him publicly so that his classmates would realize his strengths and so that Dante would, in turn, develop the self-esteem regarding his academic work that she felt he needed. As it turned out, Dante engaged deeply with the science curriculum and Ms. Rosario described him as a “profound thinker about the natural world.” When it came to planning enactments, Dante made sure his group was using time wisely and coming up with movements and sequences that made sense.

**Mia** lived with her mother part of the time and her father and stepmother for the other part. Ms. Rosario reflected on her family as being extremely communicative with each other in support of Mia. In fact, Ms. Rosario related that her mom and stepmom attended report card pick up and teacher conferences together, and her stepmom was introduced as her mom’s partner in raising Mia. Ms. Rosario described Mia as a strong all-around student who loved school. She also commented that Mia’s writing was beautiful in both English and Spanish, and described her as “100% bilingual.” Ms. Rosario remarked on Mia after the school year had ended that she was a very confident student though her demeanor was quiet and reserved. From the beginning of the school year Mia identified herself as a scientist. In personal narratives written mostly at the beginning of the year, she always placed herself in nature, for instance, on a camping trip or on a hike. She was vocal about how much she loved science and even the other students would identify her as a scientist early on. Ms. Rosario thought that this identification as a science person came from experiences during the previous school year. Ms. Rosario remembered being heartened by Mia identifying herself as a scientist, something she rarely experienced with girls she had taught. Though she was socially very quiet, she was also very positive, always surrounding herself with friends. Ms. Rosario reflected that everybody liked her and respected her ideas. She was in karate with some of the boys outside of school and they would often talk about how well she was doing in karate and who she took down over the weekend. Ms. Rosario described her as having a quirky style with her hair and clothes. Although they wore uniforms, she would add something or change something in unique ways. All year long, she was quiet and respectful, but up for a challenge and followed through. In science enactments, Ms. Rosario described her as having very good ideas and able to vocalize them.

**Javier** lived with his mother, father, and older siblings. Ms. Rosario reflected on some academic struggles, such as with writing, in spite of his strengths at conceptualizing ideas and communicating orally in both Spanish and English. Javier's spelling was described as more "transitional" from Spanish to English rather than bilingual. Ms. Rosario reflected on his need to participate vocally in class and be heard by his classmates. His ideas were creative, she recalled. It was clear that Javier loved science and trying to get to the root of complex ideas about how things worked in nature was particularly stimulating to him. Ms. Rosario felt that when it came time to do embodied performances, Javier never had to be encouraged to participate because he always found the motivation to do a good job with any group. Despite social/emotional concerns she had for him, she believed he had an important year of personal and academic growth in fifth grade and pointed out science as being one of the places he was able to truly shine.

**Yasmin** was being raised by her mother and her mother's parents. Her mom, for the past several years had been studying biology and had recently graduated from college with a biology degree. Ms. Rosario described Yasmin's love for science in fifth grade as stemming from the time she would spend with her mom doing research on the different science topics they were learning about at school. Her mom was traveling to present at conferences, and "this made an impression on Yasmin." Ms. Rosario explained that in third grade Yasmin received special education services but by fourth grade her scores were strong enough and she was on par with her cohort which gave her a "huge boost to her self-esteem."

**Leo** lived with his mother and father as well as older siblings. Ms. Rosario described Leo as “the moodiest boy in the classroom.” Leo, however, loved reading and loved to be a leader in his reading groups. He often said that if there was anything to know, he would just read about it, such was his confidence with reading. Ms. Rosario also described him as an advanced reader for his age level. Leo had a strong personality and was often outspoken during science discussions. Leo often talked about how he was a “latchkey kid” who came home after school to immediately play videogames, although his parents demanded he continued karate. He was the youngest sibling in his family by a wide margin–his other siblings were in their twenties–so he had more freedom than most kids in his class and they respected him for it and for his strong leadership skills. Anytime Leo could take the lead in conversations he was on task. Despite his freedom at home, he always did his homework. His peers enjoyed when Leo would talk at length on a variety of subjects. Ms. Rosario struggled to get him involved with most group work, although he was an active participant in science enactments, especially toward the earlier part of the year.

## E. Researcher’s Role and Positionality

During the data collection year, I took on the role of a participant observer (Emerson et al., 1995). When I entered the classroom, I was greeted with a warm welcome, waves and smiles from each table, and invitations from several of the more outgoing students to come see what they were working on. But this did not mean that at other times, the students did not position me as more of an outsider looking in. They may have perceived me as an authority figure at times, since even though they knew I was a graduate student, they also knew that I used to be a classroom teacher. I was constantly aware of this perception and did my best to be critical of my role as someone who was there to be learning from their thinking, their ideas, and the work they were doing in their science class. Early on, I developed a good rapport with the students, and they were comfortable talking with me. I used both English as well as limited Spanish, especially when talking with the few students who were not comfortable conversing in English. This undoubtedly led to a few giggles and whispers from savvy, observant students, but over time this lessened, and the students got used to my, wobbly at times, attempts to speak Spanish. Sometimes I sat down at the side of the classroom to write fieldnotes. Other times I moved about the classroom, closely observing and at times interacting with students as they engaged in science thinking or planning embodied performances, as well as recording and observing their discussions and reflections as a whole class.

I was an outsider, culturally, linguistically, and historically, of the communities in which the Latinx students in Ms. Rosario's class lived and participated on a daily basis. I am a White woman, and a former elementary school teacher with elementary-school-age children, whom the students often asked about. My background in undergraduate theater and several professional theater productions, as well as teaching theater to children, led me to graduate school with an interest in arts integration, particularly in mathematics and science. While in graduate school, extensive reading in the areas of sociocultural approaches to learning and identity construction led me to shape the research I wanted to focus on. Being involved in the larger project, the partnership between school- and university-based educators designing and studying embodied performances in science classrooms connected me to Ms. Rosario, a member of the project, and even before the data collection year, I had been observing in her class and collecting pilot data.

As an elementary school teacher, I used performing arts, mainly theater, in order to help students connect with learning on a personal level. I found that using drama pedagogy infused collaboration and fun into the classroom as well as facilitated the bridging of the emotional and intellectual life of children. The theater experiences I have had in my life have helped me learn about distant concepts, time periods, and ideas in a personal and meaningful way. As a teacher, I wanted to bring that kind of powerful learning and collective energy to my students and learn from their representations. Whether it was reenacting a Civil Rights march, role playing a Mars mission, writing and performing an anti-bullying play, or acting out mathematical equations using dance moves, I used movement and theater in my classroom as a practice of bringing students and abstract ideas or distant times and places closer together. In graduate school, I became particularly interested in investigating students' learning of science through embodied learning and the integration of artistic processes, especially in learning contexts with a large majority of students from historically marginalized groups, and students from groups underrepresented in science, both in higher education and in science-related careers.

Equity in science, in terms of access to science, expansion of who does and what counts as science, and social transformation using science as a tool (Philip & Azevedo, 2017), is an important issue to me on a philosophical and personal level. My father, as a Jewish teen in the 1950s was not able to attend his university of choice and pursue a scientific career because of quota rules at the time. As a young girl, his stories of anti-Semitism when he would venture out of his own neighborhood on Chicago's West Side in the 1940s and 50s, and my parents' participation in the Civil Rights movement in Washington, DC, made a lasting impression on me. I was brought up to recognize injustices and wanted to join the fight for a more equitable society for as long as I can remember. Bearing witness to the atrocities of the current US administration's inhumane treatment of families on the US/Mexico border while at the same time knowing the resilience and brilliance of children who cross the border, have deepened my commitments to equity through science education research.

## F. **Data Collection**

One of the defining characteristics of case studies is the use of many and varied data sources (Yin, 1994) that lead to greater understanding of the phenomenon because they represent different pieces of the puzzle (Baxter & Jack, 2008). The data for this study came from approximately one to two hours per week, over a school year, that Ms. Rosario devoted to the science part of the integrated water curriculum. Ms. Rosario often planned for the embodied performances at various stages of development to coincide with my visits, and on several of my visits I also captured a variety of other multimodal science activities such as making posters and diagrams, Socratic Seminars, experiments, and group projects. A few weeks throughout the year were skipped due to various reasons, including standardized testing or fieldtrips.

Data were collected to understand the students' science learning and identity construction relative to their engagement in embodied performances and other multimodal communication (Table II).

### 1. **Fieldnotes**

Fieldnotes for this study focused on direct observations of actions in the classroom and what was present in the physical environment, as well as my interpretations (Yin, 2011). I jotted down on a notepad how science ideas were being constructed and how students were interacting with their peers and teacher. Notes were taken on other relevant issues, but attention was paid to ensuring the notes would support understandings related to my research question. I transferred fieldnotes to word files as soon as possible after each class I observed, and wrote additional

**TABLE II**
DATA SOURCES

| Data Sources | Description |
| --- | --- |
| Fieldnotes | • Wrote down what I noticed and who said/did what as well as my interpretations and questions. I did this on several visits for at least part of the visit. |
| Artifacts | • Posters/Concept maps<br>• Pages of students' science journals<br>• Science investigations<br>• Teacher's assignments on the board<br>• Photographs of any props made<br>• BAS (Being a Scientist) handout[5]<br>• Reflections students wrote |
| Conversations | • One-on-one with students<br>• BAS conversations<br>• Conversations with small groups<br>• One-on-one with Ms. Rosario<br>• Whole class reflective conversations after embodied performances |
| Video/audio recordings | • Videos of work related to embodied performances done in the classroom, including planning, enacting, reflecting<br>• Videos of whole class conversations such as Socratic Seminars[6] |

[5] The BAS handout in is shown in Appendix A.
[6] Socratic Seminars are discussed in detail in Illustration 13 in the findings section.

memos with more detail and interpretations. I entered these typed notes into a table that I used to keep track of data sources for each class visit. I periodically checked fieldnotes against each other with attention to any patterns emerging and any particular students' actions or comments that represented interesting points of view. I also periodically went over my interpretations with Ms. Rosario and/or the students in order to member check to increase trustworthiness (Creswell & Poth, 2018).

2. **Artifacts**

Student work was collected via photographing and categorizing it electronically, in order to preserve the students' on-going work. Often times, I took photos of student science journal pages after the class left for lunch. Student-created artifacts were also photographed, including but not limited to posters, concept maps, science journaling work, drawn models, and hands-on explorations the students conducted and were keeping track of in their written work. Even though these examples of student work were not embodied, per se, I collected them in order to help shed light on how multimodal texts and various semiotic systems afforded and constrained science understandings, as these artifacts may have informed what the students had done during embodiments. I tried to keep in mind that the embodied work the students were doing about every third time I was in their classroom could be influencing and being influenced by other written and drawn texts.

3. **Semi-Structured Conversations**

Voice recordings of open-ended conversations with students in December were based on what the students had written and drawn on the BAS handouts, a questionnaire I developed,[7] and additional reflection questions Ms. Rosario asked them to complete on their embodied performances. I audio recorded students as they explained their drawings of being a scientist and elaborated on their written reflections on what it was like being a part of their embodied performances thus far. I also had conversations with Ms. Rosario after the data collection year that were voice recorded. Transcriptions of all of these conversations were completed during the post-data collection year.

This source of data was helpful in revealing the participants' construction of reality, not just to answer the research question (Yin, 2011). Conversations with students allowed a window into both their semiotic decisions during enactments and their science understandings, but also their positionings of themselves and others. Addressing the methodological concerns of Stets and Burke (2003), what individuals feel others' perceptions of them are is important to their identity construction. During the conversations with students I asked questions such as: *What were you showing when you choose to do XYZ? How did that show XYZ? Is acting out science ideas helpful to you? In what ways? Do you have good ideas for how to act out science ideas? Does your group think you have good ideas? Who has good ideas in your group? Who has good ideas in your class? What does your teacher think is going to make a good performance? What does your teacher think being good at science means?* These types of questions had the potential to reveal identity work going on in the moment *and* science understandings. They could also offer a

[7] The questionnaire was developed the year before the data collection year for pilot research. Ms. Rosario created a Spanish translation and students could choose which version to use.

window into whether or not students felt recognition from the teacher and/or their peers for being scientific or not.

Moreover, it was important to collect data that uncovered both identities-in narratives and identities-in-practice in order to get a fuller understanding of identity construction (Kane, 2012). In order to capture identity construction in reflexive and multimodal ways, I used students' work on the BAS handout (Varelas et al., 2012) that the students completed once toward the middle of the school year and once toward the end of the school year. The multimodal identity stories that emerged, as students both drew and wrote about being scientists, were "a useful frame for examining students' emerging present identities and possible future ones" (Varelas et al., 2012, p. 80). In Varelas et al.'s (2012) study, the students' multimodal identity stories showed more evidence of sociality and more expansive science practices the more they participated in the multimodal curricular interventions over the school year. The BAS handout was a promising tool for understanding how students' identities grew and changed over a school year and pointed to useful ways of exploring the research question in a different way than in-the-moment positionings provided.

### 4. **<u>Video and Audio Recordings</u>**

The largest amount of data collected was in the form of video recordings, which allowed a full capture of semiotic choices including body movements, gestures, gaze, and speech, and captured the embodied discourse. Embodied performances were recorded as they happened, as well as during the processes of planning and reflecting in order to further understandings of where the semiotic choices stemmed from and how they were understood. Classroom science talk was also video recorded, attending also to framing enough of students' bodies to capture their embodied communication such as gesturing. A deductive approach (Derry et al., 2010) to video recording was taken, capturing what was reflective of the theoretical propositions and what could shed light on the research question. From this admittedly large corpus of video data, clips were constantly identified and categorized by date, content, and students involved in order to be most useful during analysis.

## G. **Data Analysis**

In case study analysis, attention must be paid to all of the evidence, major rival interpretations must be addressed, the most significant aspect of the data must be analyzed, and prior knowledge and expertise must be put to work in the interpretations (Yin, 2011). A general strategy for analyzing the data was based on both looking for how the data connected back to the theoretical propositions and how organizing the data in different ways could point toward what was worth analyzing. The initial tool I used to organize the data chronologically was a data trail. Given the multidisciplinary nature of multimodal analysis, “a fluidity and diversity” (Flewitt et al., 2014, p. 41) of potential data sources and analytical methods was fitting, yet also required a great deal of organization so as not to become overwhelming. The data trail was essential in order to organize the large corpus of video recordings.

Data analysis began iteratively alongside data collection and continued into the post-data collection year. After the videos, fieldnotes, photos, BAS handouts, and artifacts were organized chronologically using the data trail, I began a detailed review of the videos and field notes, with particular attention to choosing video recordings for further analysis that were (1) spaced across the school year and (2) rich in multimodal communication and/or specifically captured a variety of embodiments of science ideas. This was a process of delimiting the full range of data I had captured, in order to select the videos I would further analyze versus the recordings that were outside of the focus of my research question. In order to engage further with the videos I selected according to these criteria, I watched them, not necessarily in order, and noted in an events matrix (Miles & Huberman, 1994) the date, the participants, and the activities (Table III). I used Halliday's metafunctions of communication to map the embodied performances along ideational, interpersonal, and textual dimensions (Halliday, 1978; Varelas et al., 2010). Analysis of movements that children came up with as ways to express ideas provided insight into the textual metafunction. Identification and interpretation related to the science understandings that the students represented informed the ideational metafunction. Analysis of the social interactions at play, indicated by gaze, speech, giggling, body positions, and other clues informed the interpersonal metafunction. The three metafunctions served as analytical tools for linking learning and identity construction as they unfolded in each of the videos. Watching the videos with this analytical focus allowed me to begin to understand the various meanings being negotiated in each of the episodes, which I noted in the events matrix.

This took many viewings of each of the videos while I created memos and did pattern matching (Yin, 2011). As initial themes were emerging from this level of analysis, I transcribed sections of videos in multimodal ways, attending to talk, gesture, and whole body movement. Along with writing the words spoken, I also captured screen shots of the video at relevant moments. I also transcribed all of the BAS conversations from the middle of the year, which I had audio recorded.

**TABLE III**
EVENT MATRIX SAMPLE

| Date | Topic | Learning Activities | Ideational | Interpersonal | Textual |
|---|---|---|---|---|---|
| Oct 4 | Water Cycle | Draw diagrams of water cycle with vocabulary<br><br>Plan a movement for each part of the water cycle in groups | Water collects in bodies of water<br><br>Water evaporates and forms clouds | Mateo giggles and hesitates. Yasmin taps him to do his movement<br>David bold with his actions, confident<br>Camila shy, hides her face and laughs | Mateo crosses forearms while Shape change of bending at the knees, shifting his weight to balance on the balls of his feet to represent collection,<br>Yasmin wiggles fingers upward, making use of the bounded Space immediately above her head, to represent evaporation<br>Camila brings fists together to represent condensation with light Effort<br>David bends knees, fingers wiggling down to represent precipitation with sudden Effort |
| Oct 11 | States of Matter | Class enactment of glass of water changing states from solid, to liquid, to gas | Water Molecules are tightly bonded in solid state, then spread out as they heat up | Mia boldly starts the movement. Others seem unsure and whisper.<br>Leo goes in opposite direction from the rest of the group | The group interlocks arms. They are representing the solid state, creating an enclosed, tight Space. They back away and break their bonds, widening the Space in the middle of the circle.<br>Moving around swaying arms in liquid state<br>In this transitional time, not sure where to go now that in gaseous state, shifting gazes, meandering directions |
| Oct 25 | Evaporation | Planning out posters describing results in groups | When water is poured into sand, it soaks in and | Dante excited to share his ideas. Javier picks up on Jessica's idea. Working well together, listening to | Dante gestures in each hand representing water soaking into the sand and water evaporating. His movements are quick and face bright, rapid speech |

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| | | | evaporates over time<br><br>Water in covered clay cup goes through water cycle | each other, in forward leaning postures<br><br>Dante explains carefully to others | Dante rapidly changes gestures in both hands, aligning with his rapid thoughts while explaining that the water is trapped in the cup and has nowhere to go when it evaporates. |
| Nov 1 | Water Cycle | Groups of 6-8 students planned and enacted embodied performance of water cycle | Water evaporates and water vapors condense into clouds | Leo. is eager to lead and be the group's spokesperson while they are planning their enactment. | Eric gets up to standing while wiggling his arms and fingers around to represent evaporation. Then he begins making a repeated bunching gesture, with his hands in his mid-reach Space in front of his torso to represent vapor condensing into clouds |
| Nov 29 | Permeability of earth materials | Whole class enacted water flowing through various earth materials | Water fills in the spaces between grains of sand | Students are smiling as the "water" is poured. Lots of giggling as the students playing the "water" pass between the students playing the "sand" | The students playing the sand provide some resistance, shifting their weight forward, shifting gazes among them, so the students playing the water can't completely pass between them. Some students playing the sand travel toward the middle and back with the water to represent the mixing of sand and water, the idea of "wet sand" |
| Dec 13 | Groundwater and Aquifers | Groups planned and enacted embodied performance of aquifers | Groundwater that raises higher than the water table becomes a lake | Class is giggling at Manuel's sound effects as the rainstorm | The girls playing the water in ball Shapes under the space provided by the physical table. Manuel sustains his storm sounds while repeatedly flicking the lightning bolts on his headband to create movement |

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|---|---|---|---|---|---|
| Jan 17 | Flint Water Crisis | Socratic Seminar | The government lied to the people | Urging of classmates to talk. | Weight shifts toward the center of the circle more prominent as emotional intensity increases. Facial expressions go through changes, more focus and sustained attention |
| Feb 14 | Decision of the Flint government to switch the water source | Groups of 6-8 students planned embodied performance of flint water crisis | Because they wanted to save money, they switched to Flint River, more polluted so more chlorine needed | They embodied their idea of people in power, showing excitement about money that the characters they portrayed had. | Put dollar signs over his eyes. Oliver and Ethan hugging, locomoting, jumping, slapping on the back. T-shape represents the water source switching |
| Feb 21 | How lead got into the pipes in Flint | Groups of 6-8 students finished planning and enacted embodied performance of Flint water crisis | Without corrosion control, the chlorine broke down the scale, contaminating the water | Leía directing the group. Mia and Sandy laughing at student covering his clothes with ripped up construction paper | The students joined hands and feet, creating a defined Space that represents the inside of the pipe for first the chlorine to walk through, then the water while the pipe performers dropped pieces of black construction paper onto the water performers as they passed through. |
| April 11 | Human Body systems | Students planned embodied performance of human body systems | The heart and the lungs work together in the respiratory system | Yasmin and Isabel giggling playing the parts of the nose and mouth. | Alan, playing the air, moves in at the nose and mouth and travels back between Leo and Ethan, the lungs, and around the heart. Leía's movement for the heart involves pumping her arms in a repeatable action, bent at the elbow with fingers curved inward |

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|---|---|---|---|---|---|
| May 2 | Human Body systems | Groups of 6-8 students planned embodied performance of human body systems | Circulatory system is influenced by body activity level | Collaborative group. No one leader but several voices explaining and coming up with ideas. Giggling at the heart dance. | The blood, oxygen performers going faster through the “veins” when exercising. |
| May 9 | Human Body systems | Groups enacted embodied performance of human body systems | The skeletal system needs calcium to be strong | Planning out the enactment involving other kids than just Dante. Impatience to get it done | The tug of war with strong Effort from both the blood and bone performers as the blood takes the calcium from the bones |

In order to analyze the children's body movements, I made use of the Laban/Bartenieff Movement System (LBMS) (Fernandes, 2014; Studd & Cox, 2019; Tsachor & Shafir, 2017, 2019), which allowed me to make sense of body movement along the dimensions of Body, Effort, Space, and Shape. In LBMS, Body refers to *what* parts of the body are moving, such as head, forearms, torso, etc., and the movement action, such as jumping, locomoting, leaning, and so on. Effort qualitatively describes *how* the body moves, such as strongly or lightly, or drawn out or sudden. Space describes where the body is moving in the environment, for example, the path traveled from one part of the room to another, or what direction the body is facing. Finally, Shape is in reference to the way the body changes in relation to itself and the environment. For instance, the movement of wiggling fingers upward to represent evaporation can be understood as the Body part and action of moving fingers and forearms, with head and neck engagement, Shape reaching upward with light but bound Effort in a contained mid-reach Space, followed by retreating Shape change if the child quickly drops the movement. Using LBMS helped bring out the varied aspects of movement, and led me to ask how might Body, Effort, Space, and Shape of childrens' movements illuminate children's science knowledge and identity construction?

I then composed thick descriptions (Geertz, 2003; Ponterotto, 2006) for each of the 14 videos selected. Analytic themes were revealed through "simultaneous and iterative data collection, analysis, and memoing processes" (Creswell & Poth, p. 87) and writing and further analyzing the thick descriptions of the video recorded data. To analyze the spontaneous and planned embodied performances, I focused on synthesizing how the various modalities that made up the embodied performances and other classroom communication (e.g., body movements, gaze, gestures, language) supported students' meaning making of science concepts and processes along with developing science identities. This required many repeated viewings of the whole of the "communicative activity" (Flewitt et al., 2014) focusing intensely on one of the modes at a time, and then putting them all together.

From these thick descriptions and discussing them in depth with other research team members, emerged many themes that related to identity and knowledge construction. Through writing about each of the themes and then performing cross comparisons among the themes, I was able to lump similar ones together which resulted in four larger themes. These larger themes are presented as the findings of this study and in order to bring these themes to life for the reader, I selected out of the thick descriptions, and then further refined through the writing process, what I refer to as *Illustrations* of each of the themes.

## H. **Maximizing Trustworthiness**

The criteria for increasing trustworthiness in qualitative, interpretive cases studies includes member checking, describing the context in detailed ways, tracking participants' "evolving insights and sensitivities," and "confirmability" (Guba, 1981, p. 81). The measures I took are in line with Shenton's (2004) suggested methods for meeting Guba's trustworthiness criteria including writing thick descriptions, developing extensive contextual knowledge, writing the methods in in-depth ways, triangulating data, and recognizing the limitations of the study (these limitations are shared in the Discussion chapter).

Instead of simplifying each episode first, I took the more analytically intense route of describing the episodes in great detail using thick descriptive writing. Themes emerged while writing the thick descriptions, going back and forth between the raw data and my interpretations many times as I wrote. With these descriptions I was able to harvest the complexity of each episode first, increasing trustworthiness of data interpretation and the confidence in the findings that eventually emerged.

Accounting for and theoretically describing learning that takes place in our bodies presents a challenge of validity. I often asked the students questions about how they were choosing to show concepts with their bodies. For instance, if students moved their arms in a particular way and wiggled their fingers, I would ask about their decision for doing so in order to have a window into their semiotic choices. Asking students why they were doing certain movements and how these related to the ideas they were trying to convey or understand allowed me to overlay my interpretations with their own. This helped reduce “the risk of chance associations and biases” (Maxwell, 2013, p. 128).

Additionally, at regular meetings with Ms. Rosario in order to discuss how to involve embodied performances and how they might align with the various science topics of her curriculum, we discussed our interpretations and whether we were noticing similar patterns. Furthermore, viewing clips during the post-data collection year and having conversations together, Ms. Rosario and I discussed and refined interpretations of what the students were doing and why. Videos were also periodically discussed among Ms. Rosario, other collaborators in the larger partnership, and myself.

# V. FINDINGS

Four themes emerged during a range of activities from spontaneous to planned performances in Ms. Rosario's science class, which capture the forms and functions of embodiment in relation to children's science learning, considered as both knowledge and identity construction (Varelas et al., 2015). First, collective meaning making and positionings ebbed, flowed, and built in multimodal ways. Second, dialogic reflections of embodied performances created opportunities for identity work and revision of models. Third, multiplicity of embodied performances allowed the audience to engage in multiple interpretations and identity work. Fourth, perspective-taking engaged children in knowledge construction and agentic identities.

In these themes, science knowledge–understood as an interweaving of science concepts, ideas, and practices with sociopolitical understandings related to the social world focusing on social justice–and identity construction–expressed in terms of individual and collective science identities–are inextricably linked. However, in presenting each theme, there are sections devoted to either knowledge or identity construction in order to elaborate on ideas. Each theme is introduced at first, and then brought to life through illustrations. These illustrations involve multiple children as they grappled with simultaneously complex understandings of water at the micro, macro, and sociopolitical levels, as well as who they were becoming as science people–young people who understand how water changes at the physical level as it cycles through the natural world as well as agentic participants in understanding and communicating to others how water gets delivered through systems that are fundamentally linked to injustices impacting human health. Discourse within each illustration is presented multimodally–with words spoken and images as snapshots from videos–wherever possible. Laban/Bartenieff Movement System vocabulary is used throughout the multimodal discourse analysis in order to describe the Body, Effort, Space, and Shape of childrens' movements (see Appendix C). The illustrations sample a variety of multimodal activities, and present data both from focal children and other children to capture the depth and breadth of the forms and functions of embodiments in Ms. Rosario's science class.

## A. **Collective Meaning Making and Positionings Ebbed, Flowed, and Built in Multimodal Ways**

Children engaged in sophisticated meaning making of science ideas in various modes beyond just speech and writing–including gesture, whole body movement, drawings, dance, props, and costumes–when afforded opportunities to use their own bodies and other multimodal tools and resources to construct and communicate science ideas. As groups planned their performances, they made intertextual connections (Varelas & Pappas, 2006; Varelas et al., 2006) to various multimodal texts, including videos they had watched together in class, posters around the room, and videogames from their everyday lives. As they communicated multimodally, they also transduced across modes (Bezemer & Kress, 2008), further clarifying their ideas but also positioning themselves as certain kinds of people. With the expectation to come up with a group performance by the end of planning time, or a poster that would synthesize their understandings of an experiment, these collective and highly creative projects heightened also their collective responsibility to one another's understanding, not just their own. Also, planning original performances and other group projects afforded the space for identity construction in science as children were encouraged to bring their ways of being in other areas of their lives into the classroom. A set of illustrations are described and interpreted below to show how collective meaning making, in which children took up others' ideas and added their own, was unfolding and was intertwined with identity work. The children's words and movements complimented, repeated, and at times contradicted each other, as translation within modes and transduction across modes exposed affordances and limitations of the various modes employed.

### 1. **Illustration 1: Spontaneous Gesturing at Dante's Table**

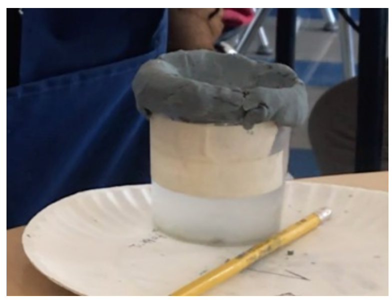
In late October, an idea for a science experiment came from a book the class was reading together called *A Long Walk to Water* (see Curriculum Table in Methods), in which one of the protagonists, Nya, finds water by squeezing clay where a lake had dried up. This book laid the groundwork for the students to think about access to clean, drinkable water as an enduring human rights issue, spanning places and peoples near and far, which they would revisit later in the year when explicitly learning about the Flint, MI water crisis. The class would eventually be constructing their own models of aquifers to learn how fresh water collects underground and how it is then distributed to people and places. So, in order to give her students firsthand experience noticing how water acts as it moves through the earth, Ms. Rosario wanted her students to observe and think about what would happen when they poured the same amount of water into three cups, each with a different earth material–sand, gravel, and soil (Figure 1). In a fourth cup, she instructed each group to put a flattened piece of clay over the cup that also contained the same amount of water (Figure 2).

**Figure 1**

*Cups with Similar Volumes of Gravel, Soil, and Sand Mixed with 100 ml of Water*

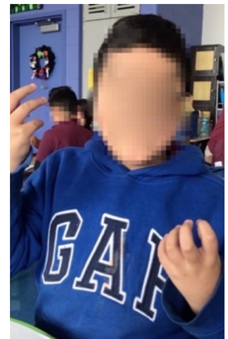
**Figure 2**

*Cup of 100 ml of Water with Clay Enclosure*



The following conversation can be viewed as an embodied and multimodal communication act in which speech and gestures co-occurred. At the table where Dante, Javier, and Jessica were working together, the students brought in embodiment in the form of gestures, coupled with speech, as they were planning their final poster after several days of observing the water in each cup. In the sand cup, they noticed that the water level had dropped relative to the original level. As they were discussing the drop in the water level they used speech and gesture in intertwined ways.

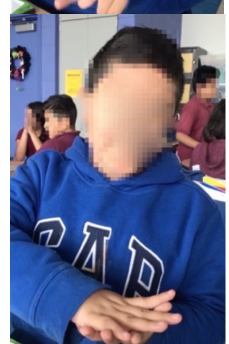
1 Dante: …Some [water] was evaporating [his right hand goes upward with light Effort] and sand was soaking it [his left hand goes downward with sudden Effort, fingers clenched together in a ball Shape].



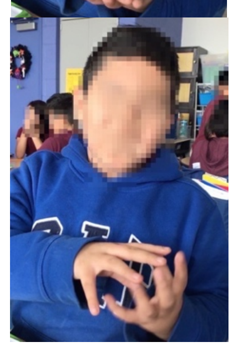
2 Dante: Sand was soaking it [pushes both hands down, the Shape of his hands spreading]

3 Dante: but it was still evaporating [his fingers in his left hand are wiggling upward extending the Space of his kinesphere, while his right hand is moving down, similarly to his previous gesture].
So it was soaking it and evaporating at the same time


4 Dante: so that's why it was dropping [he pushes his right hand down into his left hand with direct Effort]



5 Dante: and that's why it was sunk [the two hands move in opposite directions making a ball shape]



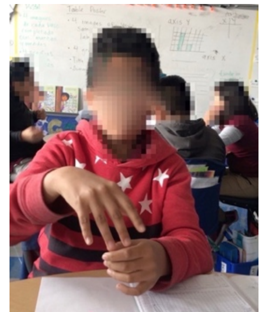
| | | |
|---|---|---|
| 6 | Dante: | but it was still the same [hands remain in a ball shape with loose interlocking of the fingers]. |

Dante consistently positioned himself in small group and whole-class discussions as an active participant, raising his hand often and sharing his ideas with excitement and urgency. His interest in figuring things out was apparent from his wide-eyed facial expressions, forward-leaning posture, and gestures that co-occurred with his speech, positioning him as someone who enjoyed science, was curious to figure things out, and eager to share his ideas.

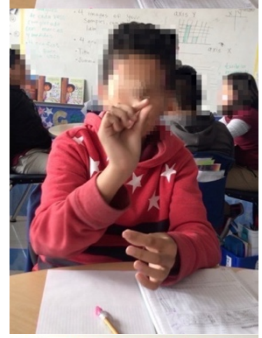
Dante's gestures and speech repeated the ideas of evaporating and "soaking in" (units 1-3). His gestures showed evaporating and soaking simultaneously (unit 1) before his speech reflected this idea (unit 3). Dante made distinct iconic gestures with each hand (unit 1–his right hand represents the water and his left hand, the sand. When he put his hands together (units 4-6), he was most likely representing that the sand and water were mixed or as he said, "the same" (unit 6). The conversation continued with Javier. My initials, RK, are used to indicate when I spoke.

| | | |
|---|---|---|
| 7 | RK: | What do you think? [to Javier] |
| 8 | Javier: | Yeah \| |
| 9 | RK: | What is he saying first of all? [to Javier] |

10 Javier: It [the water] was like absorbing [his right hand is going downward, with light Effort, into his left hand].

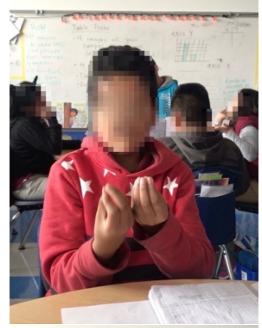


11 Javier: The sand has little holes [shows a little space between his thumb and finger] like in the middle in between them.

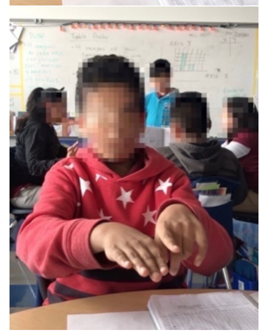


12 Javier: So the sand got // the water got passage [his right hand is making a flowing downward gesture, underneath his left hand] and then it got under it

13 Javier: and then when you touched it, it was like soaking wet [pinches both hands]



14 Javier: and then um the top you could see it a little bit, it went up [with his left hand he represents the line on the cup and with his right hand the water line going up] a little bit and the sand was higher.

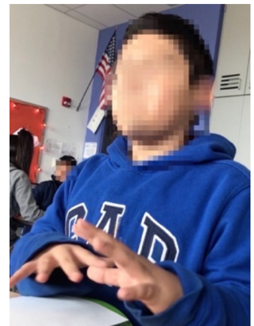


Javier's contributions were common during science class as well. He, like Dante, positioned himself as a willing participant in science talk and often gestured and leaned toward the conversation with attentive engagement when communicating his ideas. However, unlike Dante, Javier was apt to listen first to others and then build off of those ideas, as he did here. He took up Dante's idea of the sand soaking the water, translating it with his own gestures and words, and then built on it, adding two new elements. He added to Dante's initial idea of the "soaking" by describing sand as having "little holes" between that allow the water "passage" and he also represented the idea that the level of the sand rose up as the water was being absorbed.

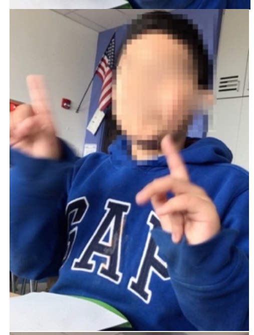
Javier also represented sand and water by gesturing with each hand, his right hand representing the water flowing into the sand, which was represented by his left hand (units 10 and 12). He made an iconic gesture of the "little holes" between the grains of sand (unit 11). His right hand then made an iconic gesture of the water flowing through the sand still represented by his left hand (unit 12). He pinched together his fingertips (unit 13) to show the closing up of the spaces among the grains of sand as the water passed through, which he associated with how the wet sand felt. He then made another iconic gesture to represent what he observed, that the level of the sand was higher as the water was being absorbed (unit 14).

During this same class period, this same group also discussed what happened with the water in the clay cup in order to figure out what to put on their poster. The following discourse includes the same students trying to figure out how to explain that the water level did not go down by much over the course of several days, unlike the water in the sand cup.

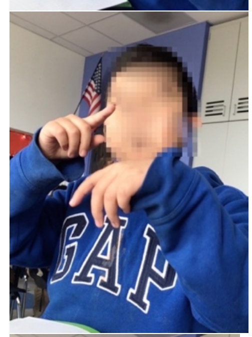
15 Dante: That clay [he means the water in the clay cup] did evaporate but like it was trapped [pushes hands down with sudden Effort]



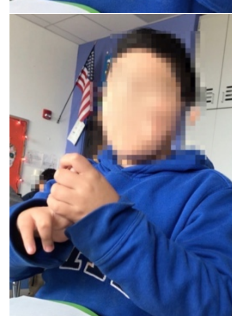
16 Dante: and didn't know where to go [both hands move upward with index fingers pointing upwards, stopping abruptly]



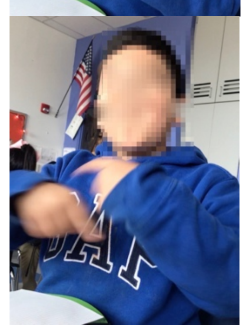

17 Dante: so it stayed there and that's why it was repeating the water cycle [both hands rotate around each other, index fingers extended]



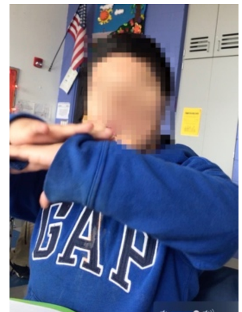

18 Dante: Yeah the same. Like sun, and vapor, and liquid [beat gestures with each word].



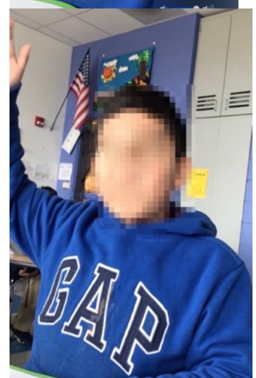
19 Dante: The same thing was trying again and again [both hands rotate around each other, similar to previous gesture]



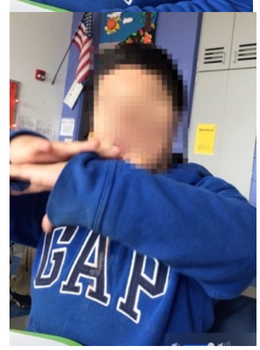
20 Dante: that's why it [the water level] didn't go down [one hand over the other, representing the water line staying the same]




21 Dante: but the other ones [the water in the gravel, sand, and soil cups] did because they had to go away [right hand moves high upward, extending his reach Space]




22 Dante: they were no like covered [both hands, right over left, as if covering something]




When Dante talked about how the water vapor got trapped, he made an iconic gesture representing his idea that the clay was not allowing any vapor to pass through it (unit 15). Then he made an iconic gesture of water vapor going up but stopping abruptly because it was contained by the clay enclosure (unit 16). He then made a metaphoric gesture of a cycle (unit 17). He used this same metaphoric gesture another time as he repeated the same idea in a slightly different way (unit 19). Then he made an iconic gesture of a covering or a top, trapping in the contents (unit 20).

Another tablemate, Jessica, had yet to contribute her thinking, which was evident in her eyes which followed Dante and Javier's words and gestures attentively. Across much of the data, Jessica was quiet and reserved, yet observant. She was not inclined to gesture or express herself outwardly but positioned herself more as a listener, but willing to contribute if directly asked. She now contributed some important ideas to the conversation, showing that behind her calm demeanor, she was actively mulling over ideas about what the water was doing at the bottom of the clay.

| | | |
|---|---|---|
| 23 | RK: | [to Jessica] What do you think about what he's saying? |
| 24 | Jessica: | What I noticed about the clay is that in the bottom of the clay it was like // um ~ drop of water. |
| 25 | RK: | [to Dante] On the bottom of the clay? Oh. Did you notice that too, that there were drops of water on the bottom of clay? |
| 26 | Dante: | Yeah. |
| 27 | RK: | [to Jessica] What do you think about that? |
| 28 | Jessica: | That it was evaporating? |
| 29 | RK: | [to Jessica] That it was evaporating. And why were there drops of water on the bottom // of the clay? |
| 30 | Jessica: | ~ When the water was starting to evaporate. |
| … | | |
| 31 | RK: | [to Javier] Did you also notice that there were drops of water on the bottom of the clay? |
| 32 | Javier: | Yeah. When we took off the clay we actually saw on the top little drips falling down. It was like kind of soak // wet. |
| 33 | RK: | The clay was soaking wet? Do you agree, why do you think that was? |
| 34 | Dante: | There was nowhere to go. Because // it was trapped. |
| 35 | RK: | Ok. What does he mean there was nowhere to go it was trapped. |
| 36 | Javier: | It covered all the // He means like // it didn't have that much space I guess? |
| 37 | RK: | [to Jessica] What do you think he means when he says the water had nowhere to go it was trapped. |
| 38 | Jessica: | The clay didn't // was // um holes where the water could evaporate. |
| 39 | Javier: | The vapor couldn't go nowhere else then like it made a little cloud on top because it had nowhere to go. (Figure 3) |

**Figure 3**

*Javier's Iconic Gesture "A Little Cloud on Top"*

First, Jessica said that she noticed the drops of water on the bottom of the clay (unit 24). She conjectured this is because the water was starting to evaporate (unit 28). Dante also thought the water was trapped in the cup (unit 15), but Jessica's idea of the "little drops of water" was a new one. Jessica primarily engaged in verbal communication. However, she also expressed this idea in a drawing that she completed later on this same day, transducing the meaning of the drops of water from verbal to pictorial mode (Figure 4). The limitation of the pictorial mode was that, in the drawing, it was hard to show that the drops of water were "under" the clay, but since she described this verbally (unit 24) we can assume this is what she intended to show.

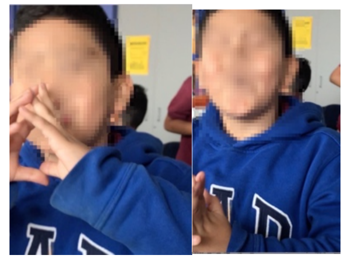
**Figure 4**

*Jessica's Drawing of the Clay Cup on Her Group's Final Poster*

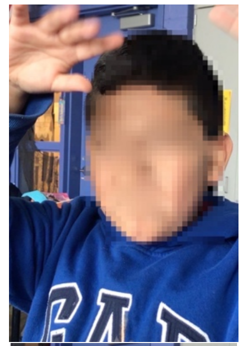

*Note.* The blue circles represent the drops of water Jessica observed on the bottom of the clay.

Javier then picked up on her idea, agreeing that when they took off the top of clay they could see "little drips of water" and that the clay was wet (unit 32). Dante then realized, because of what Jessica and Javier had shared, that the evaporating water was trapped under the clay (unit 34). At that point, it was clear that Dante understood why the clay had water dripping down from it, but I wanted to make sure the others did too. Javier's hand gesture for cloud formation (Figure 2) was iconic in two different ways–the way he shaped his hands resembled a puffy cloud, but also, at the micro-level, molecules  are more tightly bonded and closer together in the liquid than the gaseous state. The groupmates picked up on each other's ideas until they came to a collective understanding of why the drips of water on the bottom of the clay must have meant that the water cycle was happening inside the cup. Dante was particularly eager to communicate what they had constructed together, as evidenced by the quickness of his words and his constant movements as he further synthesized all of their ideas.

40 Dante: It [the water vapor] was secure. It didn't know where to go. Like clay did not go anywhere so that's why so // [he brings his fingertips together then his palms together too as he moves his hands downward]



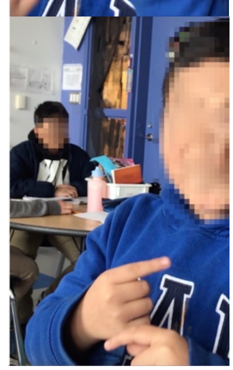
41 Dante: Right then it started evaporating [his right hand floats upward with light Effort]



42 Dante: There was a lot of vapor until there's a lot of vapor that turns to a cloud [he interlocks his fingers]

43 Dante: We could not see it but we know it started to rain [he makes a trickling motion downward with both hands]

44 Dante: so that's why it was like repeating [he extends each index finger and revolves his hands around each other]



45 Dante: it was evaporating but the line was the same…it couldn't go anywhere [his right hand goes up with fingers facing upward and with his left hand, his index finger is extended, showing the line]

Dante's iconic gesture, closing his hands together as if trapping something, represented the water vapor being "secure," within the mostly-enclosed system of the cup (unit 40). He made an iconic gesture to represent the rain he was describing as the evidence of the vapor accumulating that they could not see that formed a cloud (unit 43). He made a metaphoric cyclical gesture to represent that the water cycle kept repeating inside the cup (unit 44). With his right hand he made a metaphoric gesture for evaporation and with his left hand he made an iconic gesture of the measurement line on the cup (unit 45). Floating his hand upward was how Dante had gestured evaporation in the past, except this time he flattened out his hand (unit 41), likely representing how the vapor gets trapped under the clay.

Important identity work was happening within the multimodal communication about the cups. Jessica, who had been a quiet group member till then, was afforded expanded opportunities to contribute her thinking to the group which she took up without hesitation once invited to do so. Dante modulated between contributing and listening and Javier positioned himself as a strong listener as he synthesized others' ideas with his own. Both Javier and Dante were in forward-leaning and alert postures, indicative of high levels of engagement. Jessica's contributions, however, were a reminder that there is not one way to embody ideas.

The gesturing did offer ways to consider multiple ideas at once, and revealed sophisticated and imaginative thinking as the students grappled with two processes at the same time. Javier’s gestures were iconic, representing what he observed the sand and water doing. Dante’s gestures were a combination of iconic and metaphoric gestures. Gesturing afforded them a way to communicate two separate entities with each hand, the clay and the water or the sand and the water or two processes, evaporation and absorption, or evaporation and “raining.”

In this excerpt, two important ideas came up. One was that gesturing afforded the sign maker the ability to communicate distinct ideas at the same time. Another idea was that drawing posed a limitation in that it was hard to get across the meaning that the water drops were under the clay. Despite different modes offering different affordances, their transduction among words, gestures, and images, accumulating across all of these communication modes, contributed to their collective meaning making. Dante articulated that the water cycle was repeating itself in the clay cup only after Jessica shared her observation of water drops on the bottom of the clay. Javier picked up on Jessica’s observation and suggested that the vapor must have formed a cloud under the clay. Each groupmate brought up essential ideas for others’ thinking, in multimodal acts, and took up others’ ideas by translating (using gesturing but in distinct ways from one another) and transducing between different modes that enabled collective meaning making and pushed further their collective understandings.

## 2. **Illustration 2: Water Cycle Enactment Planning**

A few days later, in early November, the class was divided into groups of 6 to 8 people and asked to use whole body movements to show the water cycle. Throughout October, they had been learning about the water cycle, and collectively were becoming more knowledgeable about the water cycle and more comfortable using whole body movements to enact science ideas. One of the groups, Group 2, was planning in a corner of the classroom. This group included Javier, Oliver, Jessica, Manuel, Dante, and Elena. The following is an excerpt from their group planning:

1 RK: So it sounds like you guys are planning a dance.
2 Students: ## Yeah ##
3 RK: Can you explain how the dance will show the water cycle?
4 Students: ## Ok ##.
5 Oliver: The sun he's going to stand on top of the chair and is gonna aim at the water and then Manuel is gonna do the worm. And I'm gonna be evaporation. I'm gonna do the wiggle. And then she's [Jessica] the cloud and she's gonna do the ~ jubilation and who's gonna be the rain? [Groupmates try out the moves while seated, with eagerness apparent in their smiles, gazing back and forth rapidly to see one another's movements]

Oliver's interpretation of movements including "the worm" (Figure 5) are references to dances, or emotes, from the video game, Fortnite.

**Figure 5**

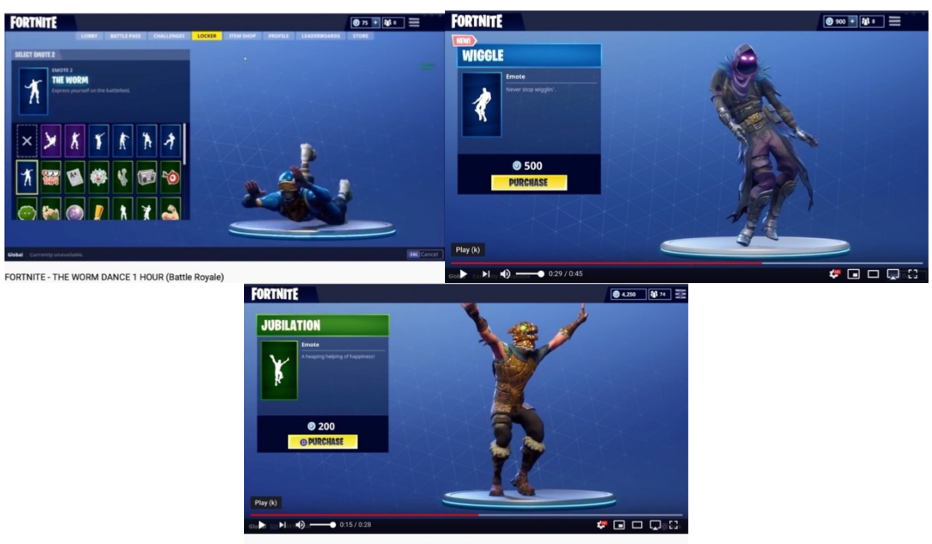
*Group's Movements as Oliver Suggests the Different Fortnite Dances*

*Note.* The group tries out the movements while seated as Oliver suggests them. From left to right, Oliver is doing the "worm," Jessica is doing "jubilation," Dante is also doing "jubilation," and Elena is doing a movement for precipitation.

These dances (Figure 6) were ubiquitous among Ms. Rosario's fifth graders, which could explain the heightened enjoyment and enthusiasm during planning time. By assigning each dance to each part of the water cycle, Oliver positioned himself as both knowledgeable about the videogame and about the science ideas because he showed how the distinct movements in each of the dances aligned well with the stages of the water cycle. "The Worm," for instance is a horizontal wave-pattern move that would fit well with showing water collection, whereas "The Wiggle" is a vertical wave motion that could represent the water vapor rising. "Jubilation" is vertical as well but involves a wide positioning of the arms which went well with cloud formation.

**Figure 6**

*Fortnite Dances That Group 2 Used in Their Water Cycle Enactment*




More group members began to participate in multimodal communication, including words, gestures, and movements. Manuel, when explaining how Javier should act like the sun said, "como dragonball z," a reference to an anime cartoon (Figure 7).

**Figure 7**

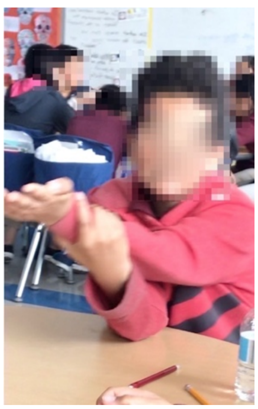
*Manuel's "Dragonball" Movement*


*Note.* The screenshot of "Dragonball z" aligns with the gesturing that Manuel is using.

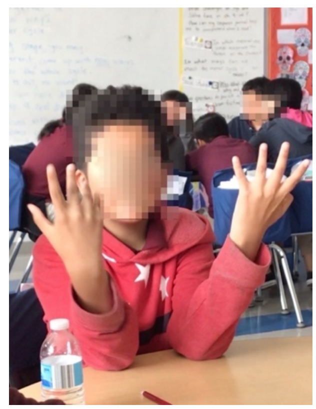
The group responded with enthusiasm, enjoying Manuel's sustained Body movements in his face, hands, and forearms, and agreed that they should include this move in their enactment. The group talked over one another with an increasing level of excitement. When Oliver got confused about the order of the water cycle and said, "First the sun, then collection, wait, no," Javier then said, "Look at the poster, look at the poster, first the sun right? Then the evaporation. Then the evaporation makes a cloud and the cloud is full of water. The water goes into the ocean that's the collection" (Figure 8). He pointed at the poster of the water cycle that was hanging on the wall near them, to show his group that he was right. As he transduced the visual images on the poster to his speech and gestures, he was, at the same time, positioning himself as a strong science learner, using visual references around him to support his claim about the order of the water cycle. The transduction of ideas from the visual references in the posters, to Javier's gestures and words, would eventually result in the order of the dance moves in their performance.

**Figure 8**

*Javier's Multimodal Communication*



"look at the poster."
*Deictic gesture*



"Then the evaporation makes a cloud."
*iconic gesture of upward direction of water vapor*

"the cloud is full of water."
*Iconic gesture of water being enclosed and the cloud being formed*

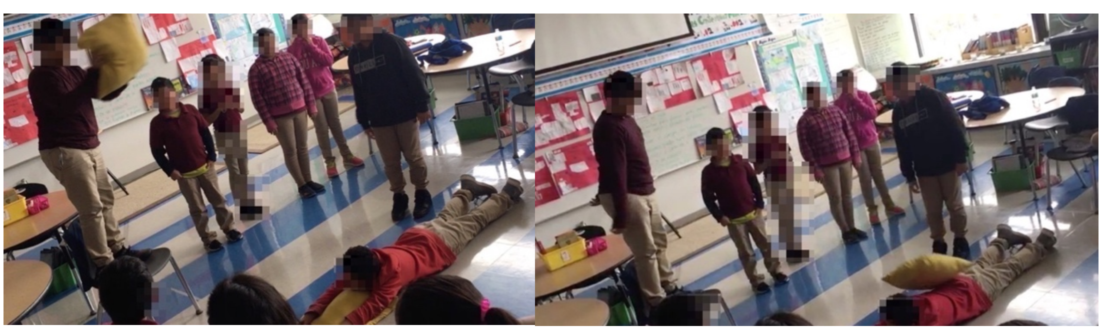
"the water goes into the ocean."
*iconic gesture of downward direction and collection at the bottom*

This is an example of the ebbing and flowing of multiple modes used and positionings performed during collective meaning making. The students, as sign makers, communicated their ideas in speech, gestures, and dance, building ideas off of one another and claiming certain kinds of knowledge, both of science ideas and of popular out-of-school multimodal activities. Words and gestures, references to dances from a videogame and movements from a show, were all ways in which they used multimodal communication to plan their enactment and position themselves as certain kinds of people, with an increasing amount of participation by all group members. They were excited to share their performance with the class, as seen through jumping, smiling at each other, and shaking their hands, anticipating an enthusiastic response from their classmates.

Their collective sense that they had something "good" to share was palpable from their smiles when it was their turn. They had clearly traded roles from their earlier planning because Oliver, playing the sun now (rather than Javier during planning time), was standing on a chair holding a yellow pillow as a prop. Oliver, representing the sun and the heat it was emitting, began the action by tossing the pillow to Javier who was representing the lake (Figure 9).

**Figure 9**

*Oliver Represents Heating Up the Lake with Sun's Energy*



Javier was in the front on the floor, face down. Once hit by the pillow, Javier began moving his whole body, doing “the worm,” in a coordinated wave-pattern motion (Figure 10). He moved around to represent the warming up of the water. There was a heaviness to his movements, a reflection of his understanding of the movement of liquid water. The audience (and the performers) laughed in response to the pillow being thrown and Javier’s movement. The audience showed surprise and excitement by shifting around in their seats and laughing.

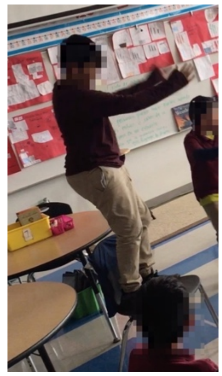
**Figure 10**

*Javier Doing “the Worm” to Represent the Lake Heating Up*

Oliver, representing the energy of the sun, was doing the “ninja style” from Fortnite, a persistent movement with straight arms, standing on the chair, filling the space using his whole kinesphere while moving his forearms in sync with each other in different directions (Figure 11).

**Figure 11**

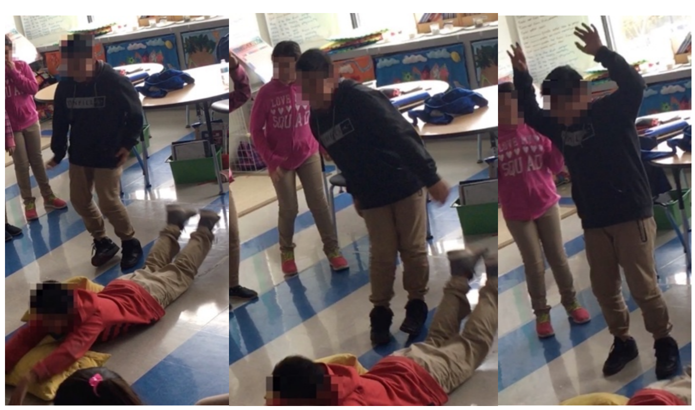
*Oliver Represents the Sun's Energy*



Manuel, playing the part of evaporation, was standing off to the other side of Javier, toward the front. Playing the part of evaporation, he began to do "the wiggle" with his whole body moving from side to side, and then he wiggled his hands above his head, a reflection of his understandings of the behavior of water vapor (Figure 12). Laughs from the audience soon turned into "Oh! Oh! Oh!" and other gleeful vocalizations as they started to realize that they recognized these dance moves from Fortnite.

**Figure 12**

*Manuel Represents Evaporation with "the Wiggle"*



In the background, Dante and Jessica, representing clouds, started performing "jubilation" and doing two distinct body movements characterized by different Effort and Shape (Figure 13). Smiling, they ran in place, with a sense of urgency, while they also repeatedly brought their hands together with slower horizontal movements in an enclosing Shape above their heads, which they later explained was meant to represent the formation of clouds through condensation.

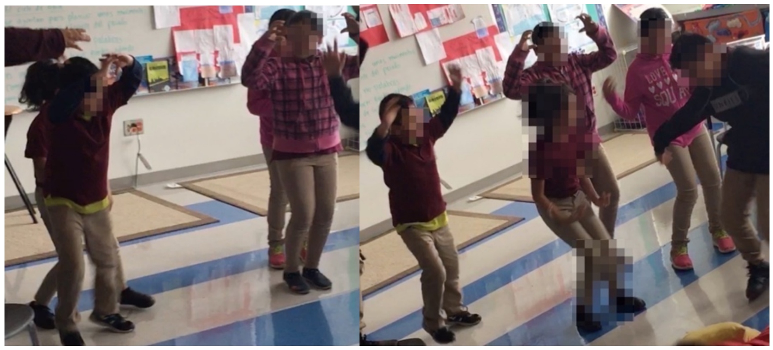
**Figure 13**

*Dante (most left) and Jessica (3rd from left) Represent Clouds With the "Jubilation" Dance*

Then, Elena and another student who were standing stationary in back of Dante and Jessica, jumped out to the front of the cloud performers to represent precipitation by moving with an Effort that was flowing and rhythmic, a movement that consisted of bending their knees side to side as they lowered their core and arms making a sinking and rising Shape repeatedly, wiggling their fingers (Figure 14).

**Figure 14**

*Students Representing Precipitation Jump in Front of Those Representing Clouds*



*Note.* Elena is the 4th from the left in the right image.

At this point in the enactment, all movements were happening simultaneously as the students made use of Space using each level by raising and lowering or simply by remaining low, medium, or high. The semiotic choices of using a variation of the Space around them, both of using different levels and of moving simultaneously, were indicative of their understandings of two major scientific ideas related to the water cycle–that it is happening at all levels of the atmosphere and that it is perpetual and concurrent. The performers' affective expressions ranged from smiling to giggling. The giggling from the audience and the performers increased as the movements got repeated. Oliver continued to move in place on the chair, Javier continued his horizontal wave-like motions, Manuel continued his wavy vertical motion, and Dante and Jessica continued running in place and bunching their hands together. Then, once they began wondering if they should stop, by gazing at each other and the teacher, the audience erupted into boisterous clapping and vocalizations.

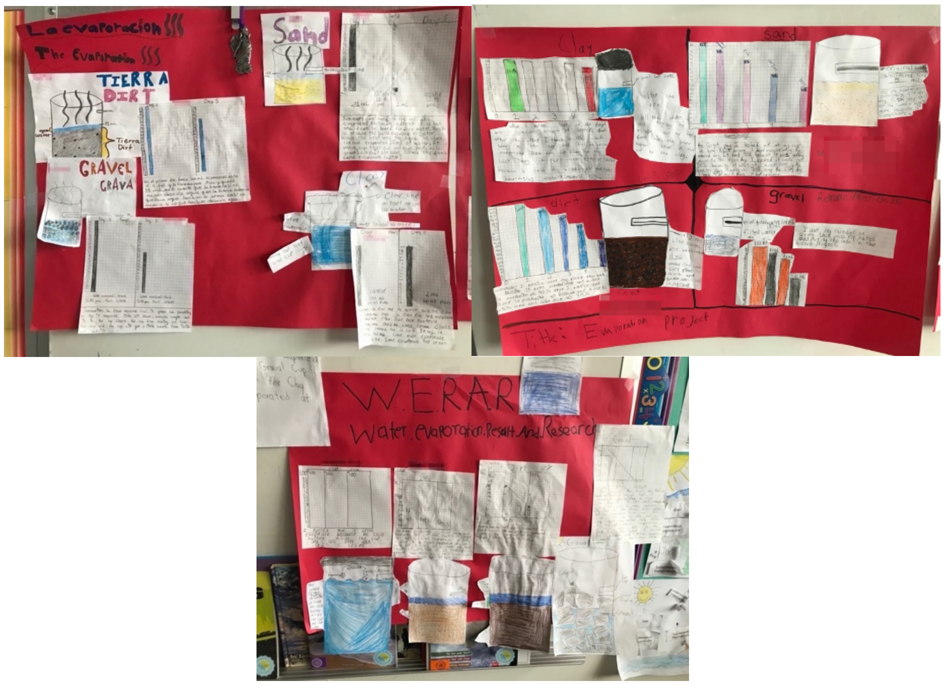
There was eagerness and joy apparent in their rhythm and quickness of the performance. The students' drive to tell the science story of the water cycle manifested itself as physical and affective effort and the commitment to their movements came through their performance. This effort did not just come through the performers. The audience was also physically and affectively reacting to the performance through vocalizations (Oh! Oh! Oh!) and tapping, moving hands and making gestures, mirroring the gestures and familiar dances of the performers. The class was engaged with a perceivable shared sense of processing and listening to each other during the reflection that followed. These dances were a shared movement vocabulary among the class, and while socially acceptable to move in these ways and perform these dances in other contexts in their lives, there was a sense of mischief and playfulness when these dances were brought into the science learning context. Using the shared repertoire of dances in this embodied performance added to the sense of joy and play that was evident in the body language of both the performers and audience. Ms. Rosario's voice was joyful and complimentary, and communicated enthusiasm for the choices the students made and their clear connections to the science ideas of the unit.

### 3. Illustration 3: Sand Group Planning

It was now late November, and Ms. Rosario's class had been learning how water moves through different earth materials. The class had completed the permeability experiment (described in Illustration 1) and made observations over several days of the different ways water flowed through and around sand, soil, and gravel. Each group completed posters that were finished and displayed around the classroom (Figure 15).

**Figure 15**

*Examples of Posters*




Today, Ms. Rosario asked the class to enact what they observed in each cup. A large group played the role of the water and another large group played the role of the sand. A few students agreed to be the audience. Ms. Rosario introduced the activity by telling the observers that they would "watch how sand behaves as water is trying to move through sand." She asked the students to move their tables out to the sides so they had space in the middle of the classroom to do the enactment and for the two groups, water and sand, to get together on separate sides of the room to decide how they were going to behave once the water was "poured" into the sand, in other words, once the water performers approached the sand performers. The posters hanging up in the classroom provided a visual reminder of what they observed during the experiment, and children glanced at the posters for ideas while talking in their groups.

The two large groups began planning separately on different sides of the classroom. The following excerpt captures the multimodal discourse that the sand group engaged in while working out their plan.

Dante, who had many times been the leader in group situations in science, began the planning by offering an initial idea. As we have seen before with Dante (Illustration 1), he was similarly eager to share his ideas and apt to use words and gestures.

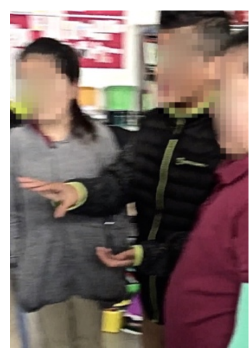
| | | |
|---|---|---|
| 1 | Dante: | Some sand is going to move because the water moves it. [he gestures with his right hand, fingers spread, pushing through space toward the left] |

| | | |
|---|---|---|
| 2 | RK: | Are you guys going to let the water through? |
| 3 | All: | No ## Yeah ## |
| 4 | Dante: | Yeah in the bottom [wiggles his fingers downward] |

Dante's iconic gesture with his hands, his right hand pushing in a vertical orientation toward the left with his fingers spread apart from one another, appeared to represent streaks of water going through the sand (unit 1). Likewise, the spreading Shape he made with his fingers could be a metaphorical gesture representing the small gaps between each grain of sand. It is hard to say if his fingers represented the sand or the water, but the movement of his forearm to the left suggests that he knew the water would move through the sand.

At this point, in order to get the rest of the group to consider their whole body movements, I asked if they would allow the water to go through (unit 2). This got a quick “No” or “Yeah” from multiple group members (unit 3), suggesting that there was not yet agreement about what to do. To this quick choral response, Dante said, “Yeah,” while he wiggled his fingers downward, “in the bottom.” What he was suggesting here, both in speech and gesture, was that they should in fact let the water through various gaps between the sand performers and not offer any resistance or try to block them (unit 4).

At this point, Javier took up this idea of letting the water through, but tweaked it a bit to capture his own understandings of the best way to show water going through sand.

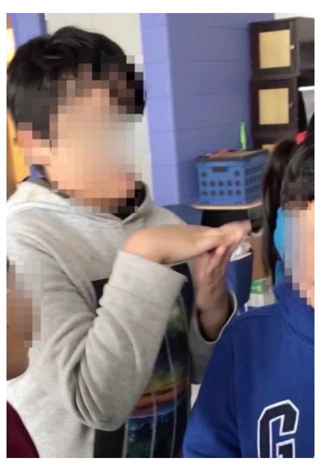
| | | | |
|---|---|---|---|
| 5 | Javier: | Wait, the water is probably going to // remember in the project, evaporation // just like the water wasn’t there anymore. No, it was like soaked in [gestures with his right hand pushing downward and left hand pushing upward]. |  |

We have seen Javier build onto the ideas of others, and here is no exception. After considering an initial idea, he was ready to contribute his own thinking, further refining it. Just like in Illustration 2 (when he referred to the posters on the wall), he referred here to “the project” (unit 5) to make his point. At first, Javier explained that the water was not there anymore because of evaporation, but then he corrects himself because he knew evaporation would not happen that quickly. Something else was making it look “like the water wasn’t there anymore." Javier reminded the group of the experiment, itself a multimodal resource, to convince them that rather than doing what Dante suggested, let all the water through, they should show that the water gets "soaked in." Javier's idea of soaking was different from Dante's idea of letting the water go through to the bottom (unit 4). Javier's iconic gesturing, his right hand representing the downward motion of the water, and his left representing the sand (unit 5), supported this thinking. The pushing upward and downward was a representation of Javier's way of thinking about the soaking process.

Next, Oliver entered the conversation, building on the previous ideas and adding something new. Oliver said, "They said in the video that it takes so long to ~," searching for the word when another student (voice coming from someone outside of the frame) in the group offered, "for the water to drop?" Oliver agrees: "Yeah, because of the sand." He was referencing a video the class watched on the topic of permeability. Oliver made a metaphoric gesture with his two hands, pressing them together as if one hand was water and one hand was sand (Figure 16).

**Figure 16**

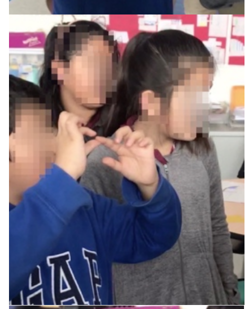
*Oliver's Gesture For the Sand Pushing the Water Down in the Cup*



Just as Javier took up Dante's idea that the sand would get through and added to the specificity by bringing up soaking, Oliver now brought up the idea of how long it would take to go through, which would have implications for how they should stand and how long the water performers should take to walk through their group. He offered the further nuance that the soaking would make it take a long time for the water to pass through the sand. By bringing a trusted resource, the video, to the conversation, Oliver was able to position himself with a strong science identity by showing his group that he had knowledge of important ideas from the video that may help them with their embodied model. Dante responded with excitement in his voice and movements with a new idea.

6 Dante: So if we're going all together [his two hands come together making an enclosing Shape as if forming a ball]


7 Dante: like, like, yeah, yeah, and then go through like tiny holes [brings both sets of pointer fingers and thumbs together]



8 Dante: and then go like that ~ [gestures a flowing motion with his hands] out slowly.


9 RK: And why will you go all together?

| | | | |
|---|---|---|---|
| 10 | Javier: | Sand is like small and when it's wet it sticks together [gestures bringing his thumb and pointer finger together in an enclosing Shape]. |  |

Dante's consecutive gestures (units 6-8) now reflected his taking up of Javier and Oliver's ideas. We have seen this kind of collaboration before from Dante in which he offers his ideas first, but then listens carefully to groupmates and modifies his original thinking, incorporating others' ideas as well (Illustration 1). He returned to his original idea, that the water would get through the sand (unit 7), but with the new ideas that Javier and Oliver added in multimodal ways, he saw that the soaking would make it go slowly (unit 8). Dante's sequence of iconic gestures showed that the water will go through the sand, but it will also take sand with it, the sand and water will mix, and it will flow slowly rather than be an instantaneous event. The ideas that each of these group members generated by building off of each other in multimodal and embodied ways resulted in a much more specific plan toward the end of the time planning for moving their bodies to embody what they noticed about sand and water. Illustration 8, presented later in this chapter, describes how the embodied performance went after planning time was over.

## 4. <u>**Illustration 4: Inside the Flint Pipes**</u>

This illustration was from later on in the school year, in February. Starting in January, Ms. Rosario's class began learning about the Flint water crisis. They had read articles, watched videos and a film, and had many class discussions before this particular activity, which was to plan an embodied performance with a group of 6-8 people related to the Flint water crisis.

This particular group was planning how to enact lead leaching into the water inside the pipes in Flint. They had decided to use construction paper in order to represent water (large piece of blue paper), protective coating (torn up pieces of brown paper), chlorine (torn up pieces of white paper), and lead (torn up pieces of black paper). A student, representing chlorine, had been busy covering his clothes with pieces of white paper to make a costume. Leía, looking at the pieces all over the student 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. Leía was one of the leaders of this group and it was clear by her reaction that the student’s use of so much ripped up paper was not what she had in mind. As they assembled to try out their idea of how to represent the pipe, some of the students, including Sandy, Mia, and Leía, formed the outside of the pipe by creating a big opening (the pipe) with a wide stance, one foot and both hands creating a large tunnel for the others to walk through (Figure 17).

**Figure 17**

*Planning for the Pipe Enactment*

*Note.* The blue paper represents the water. The bits of black paper represent lead that the water has picked up as it traveled through the pipe. The brown pieces of paper (not glued on the blue paper but captured while falling in front of the paper) represent the protective coating coming off of the inner walls of the pipe.

Leía again asserted herself with high energy, trying to organize her group before running out of time.

| | | |
|---|---|---|
| 1 | Leía: | Where's your costume Alan? Your costume! Hold it like this and when you pass through Mia and Sandy you \| |
| 2 | Alan: | Cómo? [How?] |
| 3 | Leía: | So when you pass through Mia and Sandy, when you go right here, you're gonna just flip it [the blue construction paper] over, ok? |
| 4 | Alan: | How like |
| 5 | Liam: | Cuando pasamos ahorita así [When we pass like this right now]. |
| 6 | Alan: | [flips the paper to the "dirty" side] |
| 7 | Leía: | No, show the clean side, the clean side, other side, ok? |

Leía and Liam communicated to Alan that flipping the construction paper at the exact time he was to pass by Mia and Sandy was crucial to the overall meaning. Without flipping the paper from “the clean side” to the side with construction paper pieces on it, the audience would not connect that the protective coating was breaking down, which Mia and Sandy would show by letting pieces of torn up brown paper fall from their hands, which would then justify how lead was getting into the water.

They tried it again. Everyone laughed this time when Liam and Alan, representing the water, and another student, representing the chlorine, passed through. I wanted to make sure everyone was clear on the ideas they were representing.

| | | |
|---|---|---|
| 8 | RK: | [to Alan] Ok so when you pass Mia, you flip it over to show what? |
| 9 | Alan: | Water // lead. The lead that is poisonous. |
| 10 | RK: | And then chlorine? |
| 11 | Alan: | The chemical that cleans the water. |
| 12 | RK: | What else does chlorine do other than clean the water? What’s the problem it can cause? |
| 13 | Sandy: | It can damage pipes. It can damage the protector of the pipe. |
| 14 | Alan: | So the chlorine should go first before us. Doesn’t the chlorine go //or should we go at the same time? |
| 15 | RK: | This is a good question. Look, Alan is wondering should chlorine go first, should they go at the same time, or is it good this way? |
| 16 | Liam: | He’s first. |
| … | | |
| 17 | Liam: | He’s going to damage the pipes and then the lead is gonna go into the water. |
| 18 | RK: | I have a question for you. Some chlorine is good. How can you show that this is a dangerous level of chlorine? |
| 19 | Sandy: | Maybe the chlorine when it’s passing // maybe water and chlorine can go together and we can be falling apart on this [she gestures toward the black pieces of construction paper taped all over her shirt] and to show the ~ |
| 20 | RK: | The protective ~ |
| 21 | Sandy: | That that’s a bad level of chlorine // it’s destroying the pipes and the water. |

When Sandy said that the chlorine could damage the “protector of the pipe” (unit 13), Alan questioned whether or not they should change the order (unit 14) and have the chlorine walk through first. Liam agreed with this idea (unit 16) because it was ultimately the high amounts of chlorine that caused lead to contaminate the water (unit 17). Sandy had a different idea, that the water and chlorine walk through together, at the same time (unit 19), perhaps because this would show that the chlorine and water were mixed together.

In this illustration, we see how the costumes and props created out of construction paper, the material artifacts of the enactment, supported the children to consider important ideas related to drinking water such as how much chlorine is too much and the process by which lead gets into drinking water. Their ideas about how to do their embodied performance ebbed and flowed between their movements, words, and the various ways of using the ripped construction paper. This was a rich example of multimodal communication–the ripped paper and the timing of flipping the paper, right as "lead" (Mia and Sandy) passed through, was crucial for the audience to understand that the lead got into the water. Their ideas were further constructed because of the questions that came up about the props, the timing of the action of flipping the paper, and the meanings the props carried. Thus, the children knew that the materials and how to use them, along with their actions, were communicating meaning during their enactment, and, thus, became central to the representation of science ideas they were trying to convey.

## B. **Dialogic Reflections After Embodied Performances Created Opportunities for Identity Work and Revisions of Models**

Children, along with Ms. Rosario, participated in dialogic reflections either during or after embodied performances in which they guessed what the performers were trying to show, asked questions, gave compliments, clarified ideas, and suggested revisions. This turned out to be one of the most important parts of the process because it was during these reflections when the questions that children posed led to greater understandings and expanded opportunities for children to be recognized by their peers for their contributions. The performances themselves were a concrete and shared experience within the whole class, and the reflections created opportunities for productive identity work and co-constructing science knowledge, with Ms. Rosario's guidance.

The embodied performances expanded available science identity roles and the children took up these roles during reflections in various ways. They positioned themselves as interpreters and questioners as they voiced their reactions to the enactments. They shared what worked for them and what could be tweaked and why. They asked questions because something in the enactment helped them to think about the phenomena in a new way. Sometimes, the performers' ideas did not come across in intended ways through the movements they chose. Through dialogic talk, audience and performers, along with Ms. Rosario, came up with ways to revise the embodied model to come closer to what was intended or toward a deeper understanding of the phenomena.

### 1. **Illustration 5: "They're Going Up, So Evaporation"**

The class had recently started their water cycle unit and, thus far, watched an animated video on the water cycle (Figure 18) and worked in groups on ordering various water cycle terms on a poster in a way that would show their beginning understandings (Figure 19).

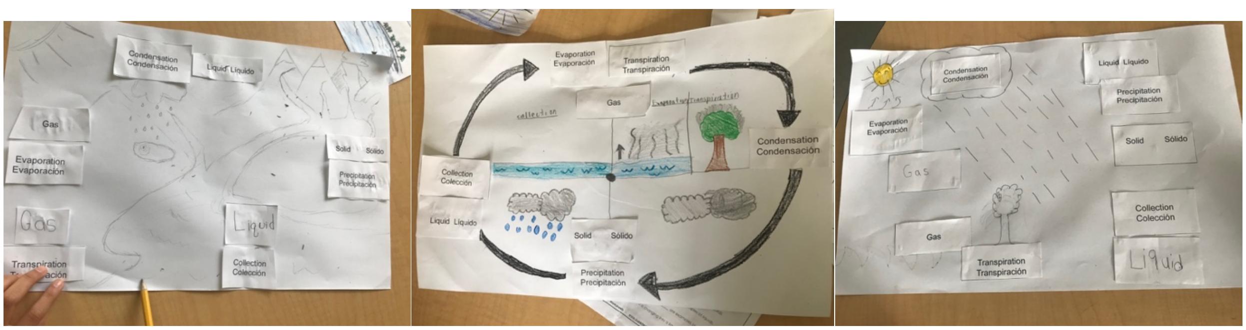
**Figure 18**

*Video Students Watched on the Water Cycle*


watchknowlearn.org Dinosaur Pee? Crash Course Kids #24.2

**Figure 19**

*Group Water Cycle Posters*

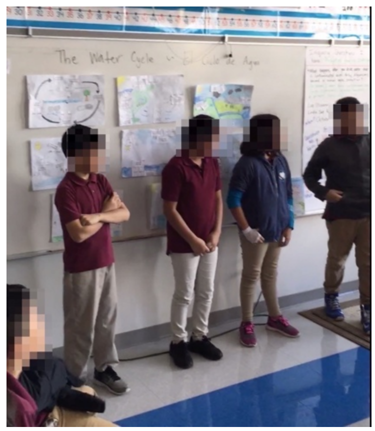



*Note.* Students were asked to cut out vocabulary words and decide as a group where to place the words within an illustrated diagram. Three unique group diagrams were created.

After completing and putting up their posters, Ms. Rosario asked each table group to come up with a distinct movement for each part of the water cycle. This was the first enactment of the school year. After each table had time to plan, Ms. Rosario quieted down the class and encouraged a rather hesitant group to begin (Figure 20). This was the very first group to perform in front of the class that year and they were visibly nervous. All four members of the group formed a line, facing the audience, giggling as they tried to maintain composure.

**Figure 20**

*Water Cycle Movements*



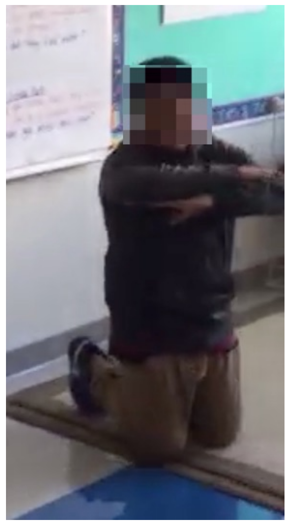
*Note.* Students from right to left are Mateo, Yasmin, Camila, and David.

The first one to perform his whole-body movement, Mateo, was encouraged by Yasmin, directly to his right, to begin the action. Yasmin was also giggling, but knew Ms. Rosario and the class expected them to get started. The silence from the audience with a small amount of chatter in anticipation and the teacher's "Shhh," created an atmosphere of a performance about to get underway. Yasmin tapped Mateo to start. Mateo giggled and hesitated to begin, exhibiting a flexible Effort in his Body, not quite focused yet. He did not appear ready, but was urged by Yasmin yet again. She whispered, "Come on," with an encouraging smile while tapping his arm to go. She, out of the group, appeared to be most able to maintain her composure and encourage her group to proceed.

In quick succession, each member of the group did a movement that represented a stage in the water cycle, starting with Mateo (Figure 21). He lowered his level in Space by crouching down on his knees, a broad smile on his face, and quickly crossed his forearms, one overlapping the other.

**Figure 21**

*Mateo Represents Collection*

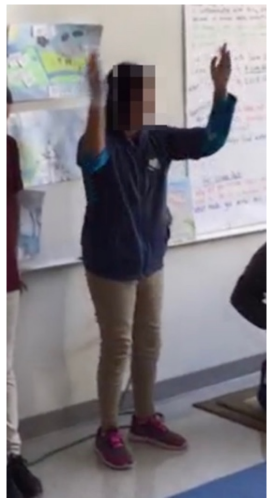


His movement was low to the ground with a horizontal orientation, likely representing the collection stage in the water cycle. He did not hold his gesture with sustained Effort but rather quickly brought his hands to his pockets, giggling while gazing at the rest of his group.

Just as Mateo put his hands in his pockets, next Yasmin (Figure 22) wiggled her fingers in an upward direction above her head.

**Figure 22**

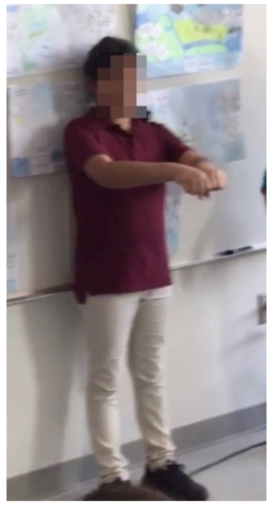
*Yasmin Represents Evaporation*



Contrasted with Mateo's lowering Shape, Yasmin's hands extended her reach-Space to a higher level. The motion she had chosen to enact, going upward in a curvy, wiggling movement indicated that she was likely representing the evaporation stage of the water cycle. She quickly retreated when she reached the outward Space of her vertical kinesphere, dropping her hands and hiding her smiles at Camila, while she urged Camila to do her movement next. Camila (Figure 23) then put her fists together out in front of her torso, bumping them together with light Effort. This motion likely was meant to represent clouds forming, the condensation stage of the water cycle. Her movement was at the mid-level, right in front of her torso.

**Figure 23**

*Camila Represents Condensation*



Thus far, Mateo, Yasmin, and Camila had represented each of their movements at various body levels (collection at a low level, vapor spreading at high levels, and condensation with clouds forming at the mid-level), which aligned with the scientific idea of the water cycle happening throughout several levels of the atmosphere.

Camila, smiling, gazed toward David to do his movement. When he started to move, Camila could not hold her giggles in anymore and erupted in laughter, along with Yasmin and Mateo, and covered her face with her hands. David (Figure 24), who had been lightly clapping his hands together since the beginning of Mateo’s movement, anticipating his turn, now wiggled his fingers as he bent his knees and went down to the ground in a sinking Shape, while saying with a cheeky smile, “and it starts all over again.”

**Figure 24**

*David Represents Precipitation*

David was representing the precipitation stage of the water cycle that ends up on the surface of the earth, falling from whatever level it was formed. By saying that it "starts all over again," David signaled that even though his groupmates were orienting themselves in a line, they understood the water cycle stages as a cyclical pattern of events.

While moving their bodies to represent science ideas, these groupmates were also doing science identity work by taking up available roles. Yasmin positioned herself as the group's leader, encouraging her groupmates to do the movements they had planned. David, in using his whole body each time he repeated his gesture and said his line, showed confidence. Mateo and Camila were hesitant to perform movements in front of the class, their Effort bounded by their nervousness, positioning themselves as students who engaged but with tentativeness.

The audience giggled along with the performers and Ms. Rosario quieted the class. She said to the group, "Do it again. Do it again. // Shh. Do it again. Make it very obvious, ok?" The group started over, again beginning with Mateo's movement and then progressing down the line rapidly. This time they were able to contain their giggles and move with more sustained Effort for a bit longer than the first time. This could be in response to their teacher's request to "make it very obvious" or because they were experiencing increased confidence performing in front of others for the second time.

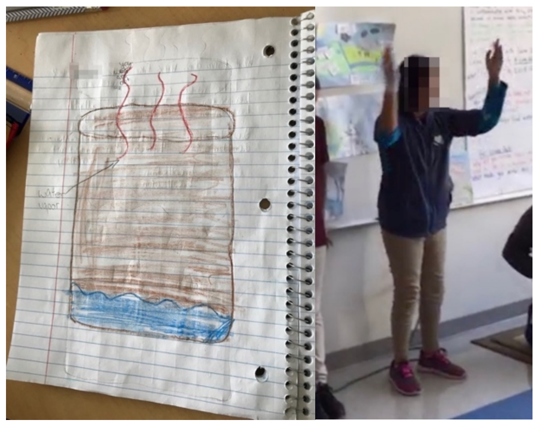
Ms. Rosario broke down each movement so the audience could follow the scientific ideas going on in the enactment. She started a discussion between the performers and the audience. This time Mateo sustained his crouched Shape in Space for longer and balanced on the balls of his feet, not immediately breaking from it as he had done previously. This allowed the class to share their interpretations of what he was showing.

| | | |
|---|---|---|
| 1 | Ms. Rosario: | Can we tell what each one is doing? Mateo, you do it again. Can anyone tell what Mateo is doing? Don't tell us group. First let's guess. |
| 2 | Oliver: | He's doing a lake or ocean. |
| 3 | Ms. Rosario: | Ok. What do you think he's doing? |
| 4 | Enzo: | He's doing solid. |
| 5 | Ms. Rosario: | He's showing us solid? Ok. Anyone else? |
| 6 | Liam: | He's showing us collection. |
| 7 | Ms. Rosario: | Huh? |
| 8 | Liam: | When the water collects. |
| 9 | Ms. Rosario: | When the water collects. So show us again, Mateo, what's your move? |
| 10 | Mateo: | [does his same movement again] |
| 11 | Ms. Rosario: | Ok, any other ideas? How about the next move? |

Ms. Rosario employed dialogic teaching moves in order to get her students talking. For instance, she did not confirm Oliver's interpretation, but rather elicited for other ideas (units 3 and 5). In a similar way, she did not confirm or correct Enzo's suggestion that Mateo was representing a solid (unit 5), but instead moved on to Liam's suggestion. After repeating Liam's idea (unit 9), she moved on to Mateo, asking him to show his movement again. Mateo did his move again, this time making it more obvious, like Ms. Rosario had asked. Rather than breaking out of his movement right away like last time, he held it. Yasmin also held her movement for longer, her wiggly fingers going upward above her head, resembling the drawing she did in her notebook, of curvy lines to represent evaporation (Figure 25), and, thus, transducing meaning between body movement and the visual image she created.

**Figure 25**

*Yasmin's Drawing and Movement of Wavy Lines Representing Evaporation*



She quickly brought her arms back down, no longer giggling, but still perhaps uncomfortable holding her movement. Ms. Rosario asked, "Ok, that one [referring to Yasmin's movement], what do we think it is?" One of the audience members suggested, "Rain," quietly to another audience member. The movement was so quick that it was not clear to the student which direction her hands were going, up or down. The dialogue continued:

| | | |
|---|---|---|
| 12 | Abril: | Evaporation. |
| 13 | Ms. Rosario: | Evaporation! Watch how her hands are going. Which direction? |
| 14 | Audience: | Oh! They're going up. |
| 15 | Ms. Rosario: | They're going up, so evaporation. |

This time, Ms. Rosario confirmed Abril's interpretation (unit 13), whereas she left the audience's interpretation of Mateo's movement more open (unit 11). Perhaps she felt that enough students agreed on evaporation (unit 14) that a confirmation of their collective interpretation was warranted (unit 15). She moved on to Camila and asked her to show her movement again, which she did. She still giggled and appeared nervous through her sinking shoulders, this second time, to have her class discuss her movement. Ms. Rosario asked for suggestions, reminding the class that they knew the vocabulary. Jorge suggested condensation but next Eric suggested precipitation. Ms. Rosario asked Eric to think about what precipitation meant while looking at Camila's hands. She was trying to draw Eric' attention to the disconnect between what precipitation meant and what Camila's movement looked like (Figure 23) so that he would have a chance to catch this mismatch on his own. She did not resolve this, but rather moved on to asking David to repeat his movement. She then went back to Eric to see if he had reconsidered his interpretation of Camila's movement. Referring to David's movement, Eric said, "It could be rain or…precipitation?"

Ms. Rosario now asked each of the performers to say what they were representing. She asked for any questions and then thanked the group for presenting. Throughout the conversation, reflecting on the performed science ideas, the 'silliness' of the group noticeably decreased as the discussion of the scientific ideas increased. Ms. Rosario devoted the time to reflecting on the ideas in the performance rather than the hesitancy of the performers. She could see that it was early in the year and the class was not used to performing for each other. Through this pedagogical choice, she elevated the science and as a result, the whole class, including the performers themselves, took on a thoughtful, reflective stance toward the performance and the ideas being communicated.

There was evidence of both learning and identity construction in their movements, but also in their commitment to their movements. Movement analysts refer to the commitment to a particular movement or character as portraying a *posture-gesture merger*. The merging of posture and gesture shows whole body engagement in that the gesture in the arms is supported by the posture of the body as a whole. In this enactment, the posture-gesture merger increased each time the children repeated their movements, underscoring the importance of dialogic reflections after the performances in order to allow the performers multiple times to do their movements and to make revisions as needed.

It is worth noting that, although evaporation means that water vapor is going everywhere in an uncontained space, Yasmin made the choice to stay in a contained vertical space to show evaporation. Although evaporation happens all around and possibly, if Yasmin would have moved her arms in various directions she could have better captured this idea, she did represent the important idea that water vapor does not travel in straight paths but with freer movement. The science ideas may require children to step outside the normal socially acceptable behaviors of the classroom in order to show them more completely. Nevertheless, movement was an important mode of communication and thinking for Yasmin. During the BAS conversation in December, when I asked Yasmin if acting out science was helpful to her, she articulated, "Yes, sometimes we ask each other what is this or how does it move? So then, like, it helps me when we enact. It helps me more because we show how we think it moves."

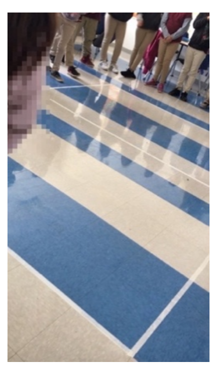
### 2. **Illustration 6: "Does The Gas Stay In The Cup?"**

In early October, Ms. Rosario's class participated in embodied performances for the second time. They had just begun grappling with how water molecules behave in different states of matter–solid, liquid, and gas. Having watched videos, read informational texts about states of matter, and seen many diagrams and pictures of ice, liquid water, and gaseous vapor in the previous days, Ms. Rosario said they would be putting the states of matter into their own bodies, acting like water molecules. The class had been discussing the states of matter, how molecules in frozen water are bonded together tightly which is what makes ice a solid. They had discussed how when ice is warmed up, the molecules become less tightly bonded. Ms. Rosario had prepared, along with the project team, an embodied modeling activity to help her students experience these molecular behaviors in their own bodies.

Students moved their tables to the sides of the classroom to create space in the center of the room. Ms. Rosario put down masking tape in a large rectangle in the middle of the classroom. She stuck another line of masking tape, splitting the large rectangle in half (Figure 26). She then explained that this large enclosed rectangle in the middle of the classroom was a model of a cup of water and the line of tape going down the middle was the water line. She explained that they would become part of the model, representing the water molecules with their bodies.

**Figure 26**

*Outline of a Cup of Water on the Classroom Floor*



*Note.* The closest end in the photo is the bottom of the cup and the furthest end is the open top of the cup. The line going down the center represents the water line.

Ms. Rosario asked for volunteers to be water molecules in the cup and for everyone else to watch. Ten students volunteered to be water molecules first, including Mia, Yasmin, Dante, and Leo. She told the "molecules" to stand in a huddle underneath the water line, linking arms to show they were tightly bonded (Figure 27). They faced the center of a tight circle with arms locked, creating what appeared as an enclosed ball Shape. Everyone else became the audience. There were two concentric circles of attention, one inner, doing the actions, and one outer, observing the actions.

**Figure 27**

*Students Represent Water Molecules in a Frozen State of Matter*


Ms. Rosario asked them, "So what happens when I first take the cup out of // ice?" The students understood that she meant the solid ice was beginning to melt, going from a solid to a liquid, and began enacting melting by backing outward from their tight circle. As a group they were communicating with each other, silently exchanging glances, but no words were exchanged yet.

The circle started backing up with some hesitation. They appear to check in with each other, perhaps confused about what to do. Mia, however, displayed confidence as she backed outward without hesitation, freeing her body in the direction of her movement as the Space increased between the actors. The others followed her lead (Figure 28). They began quietly talking at the same time as hesitantly walking outward, taking after Mia's movement.

**Figure 28**

*Representation of Ice Melting*

*Note.* Mia is at center, facing the camera in a striped sweatshirt.

Mia was smiling widely as she backed away from the other "molecules," as if to say, *I know what to do,* and her arms started to shift from being down at her sides to moving upward and swaying from side to side (Figure 29). By unhooking their arms they showed that the water molecules are not tightly bonded as the temperature increased, although in the liquid state molecules are still bonded with each other but loosely.

**Figure 29**

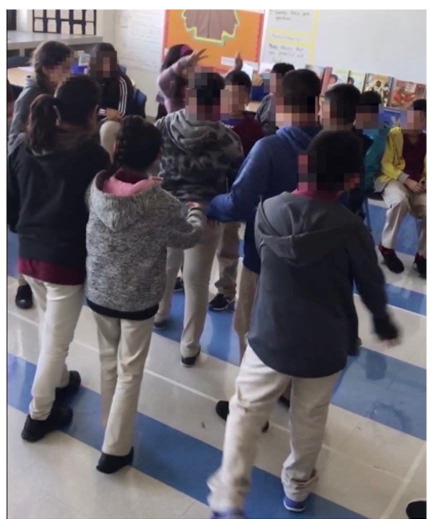
*The Ice Melts to Liquid*

Mia both positioned herself and gets positioned by others as a strong leader, willing to risk being the first to try something. She was the first to begin to break apart the tight bonds as the ice was beginning to melt and she was also the first to start to move her arms above her head to show the freer movement of molecules in the liquid state. The others gazed toward her and trusted her ideas, following her lead.

When they stopped moving and began gazing around at each other, Ms. Rosario began to offer prompts as a way of further exploring the model. Ms. Rosario asked, “So what happens first?” Leo called out but was not heard: “They all turn into liquid.” He repeated himself a bit louder, but Ms. Rosario was in the middle of saying, “You know you have to move somehow to show us the state of matter, so what happens first?” Here, Ms. Rosario was reminding the performers that they were modeling the *movement* of the molecules, rather than just standing still in the cup. With Ms. Rosario’s reminder, everyone began to move in various pathways around the Space, waving their arms and moving in various directions with similar Effort within the outline on the floor (Figure 30), but they looked like they are still figuring out what to do. Leo said, “it spreads out,” as he was thinking about what liquid water does on the macroscopic level. Of course, by “spreading,” they were also depicting an increase of volume, namely that molecules in a liquid state of a substance are further apart than when in a solid state, which is true for most substances but water is an exception. Ms. Rosario did not have any intention of discussing this exception with her students.

**Figure 30**

*Molecule Performers Represent Liquid*



At this point, the performers were mostly between the water line and the top outer line, which was not explicitly marked as the top of the cup, but the majority of the students assumed this was the case. Ms. Rosario then said to them, “Then, as the water gets to be boiling point, it’s really hot.” The performers who were lingering below the water line, in response to Ms. Rosario’s prompt, hesitantly walked above the water line and below the outer top line (Figure 31), showing that water vapor was rising.

**Figure 31**

*Students Represent Water Starting to Boil*

Leo called out, as if he just realized something, “hot,” and walked the other direction, toward the bottom of the cup (Figure 32).

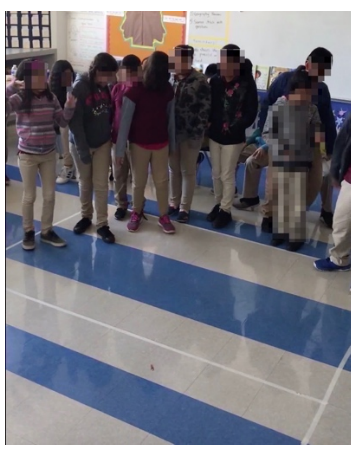
**Figure 32**

*To Show Water Boiling Leo Heads the Other Way*


Leo gestured for the others to join him, but everyone else went the other way, toward the outer top line of the cup, some of them waving their arms above their head. Leo seemed to be thinking differently about the directionality of the model. He was breaking apart from the group in order to show molecules in gaseous state escaping. However, Leo was heading to the bottom of the cup whereas the rest of the performers were getting right above the outer top line of the cup (Figure 33). They appeared unsure of what to do with their bodies, indicated by their frequent shifting of gaze from one person to another to check where each other was. Leo was not afraid to break apart from the group and go in the opposite direction. He positioned himself as an independent thinker who would strike out on his own as he was trying to make sense of the ideas the class was exploring. He was bold about voicing his ideas and verbally shared his ideas several times during the year as he tried out different ideas with his movements. During the BAS conversation I had with Mia, she attributed to Leo strong science understandings. When I asked her who had good ideas about science in her class she responded, “Leo because he helped plan a lot of cool things that are based on the real world and what’s happening.”

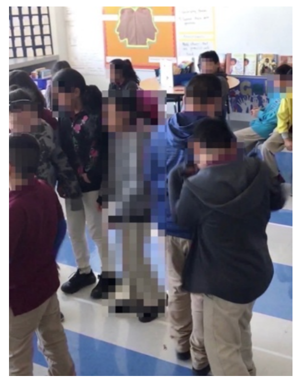
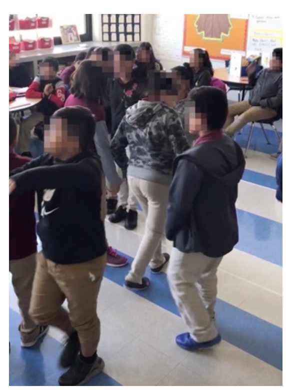
**Figure 33**

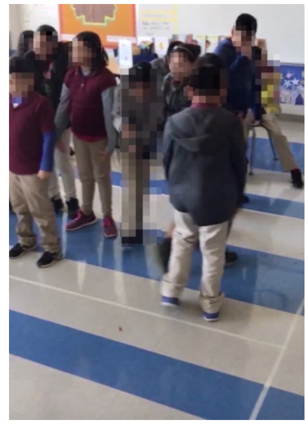
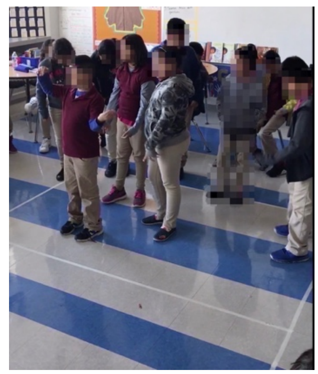
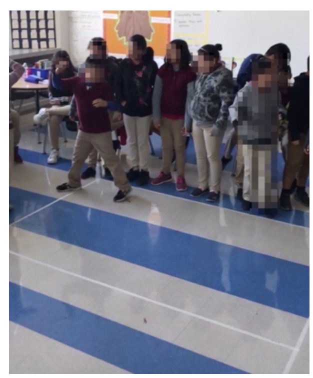
*Students Unsure of What to Do at the Top of the Cup While Depicting Evaporation*



Encouraging movement, Ms. Rosario said, “Ok, we’re still figuring it out. We’re just standing there friends.” She encouraged them to move and they started to sway from side to side while standing still, moving their arms.

The following discourse took place at this point in the enactment. Ms. Rosario, sensing some confusion both with the group's hesitancy and Leo going the other direction, decided the enactment needed revising, taking them back through the process of ice melting to liquid, and then turning to water vapor. She said, "First you melt and you're melting and you become what? What state?"

| | | | |
|---|---|---|---|
| 13 | Leo and others: | Liquid! [they begin to move freely, walking to the area underneath the water line] |  |
| 14 | Ms. Rosario: | So show me liquid first. First liquid [they continue to move around freely, swaying]. Now we're turning up the heat. Now it's boiling point. |  |
| 15 | Leo: | Now I'm turning into gas. [again, walks in the opposite direction while everyone else walks toward the top] |  |

| | | | |
|---|---|---|---|
| 16 | Ms. Rosario: | This is the bottom of the cup [correcting Leo] |  |
| 17 | Leo: | [Leo then turns around to join the rest]. | |
| 18 | Ms. Rosario: | Ok, Does the gas stay in the cup? | |
| 19 | Students: | No. [a couple of students are standing outside of the top outer line of the cup but everyone else is standing between the water line and the top outer line] |  |
| 20 | Ms. Rosario: | You all stayed in the cup there. Where do you go? [The molecules adjust to moving just above the top outer line] |  |

When Ms. Rosario told the class she was turning up the heat (unit 14), most of them went above the water line, but only a couple of students went above the top outer line. It could have been that most of them interpreted the top outer line of the cup as a closure. In this case, staying between the water line and the top outer line would be scientifically accurate. Ms. Rosario shared her observation: “You all stayed in the cup there” (unit 20) suggesting that she wanted them to move outside of the cup because she meant for the cup to be open.

This excerpt was from one of the earliest enactments of the school year. This could explain the hesitancy to move their bodies like molecules, unsure of whether this would be socially acceptable to their peers or if their movements would be what their teacher had in mind. Students were doing identity work and making scientific meanings, afforded by the opportunity to enact water molecules with their bodies and participate in dialogic talk and revisions, guided by their teacher, in the process. They were also making meaning about the states of matter through this embodied model, although there was some confusion. They were getting the chance to “try out” being water molecules in solid, liquid, and gaseous states, experiencing with their bodies the tightly bonded water molecules in a solid state. By backing away from these tight bonds and beginning to move more freely, they were experiencing with their bodies what happens when water molecules are heated up, which, despite the confusion over whether the cup was covered or not, was a worthwhile embodied experience for the children for the very reason that they got to experience, with their bodies, the movement of water molecules.

By revising the model as they went, in dialogic ways with their teacher, they had to think about where to position themselves within the model. Something about the model was telling the majority of them that they had become trapped in the cup, even when they were in the gaseous state. The confusion experienced with this particular model actually brought productive struggle into their meaning making. The only way to know whether a model needs to be revised is to test it out, which is exactly what they were doing with Ms. Rosario as their guide. Revising embodied models has the potential to motivate this kind of thinking that deepens scientific understanding with further revisions of the model.

### 3. **Illustration 7: "Rain Needs To Be Coming Under The Cloud"**

Revisiting the day in early November, when Ms. Rosario's class was working on creating water cycle enactments in groups of 6-8 students, another group, Group 3, was busy planning their own enactment. The group members included: Leía, Yasmin, Camila, Braylon, Sandy, Mateo, and another student. They had just finished a joyful planning session in which they worked well together with high levels of engagement as they developed their movements. Leía had taken the helm, and just like in Illustration 4, we see here as well, Leía's comfort with leading and organizing her group's movements. "All of us, even you," Leía giggled as she directed Braylon to get on the floor with the rest of the group, wiggling their hips, side to side with arms straight against their sides (Figure 34). Their wiggling was meant to represent collection of water in a lake. Whenever they bumped into each other, laughter erupted.

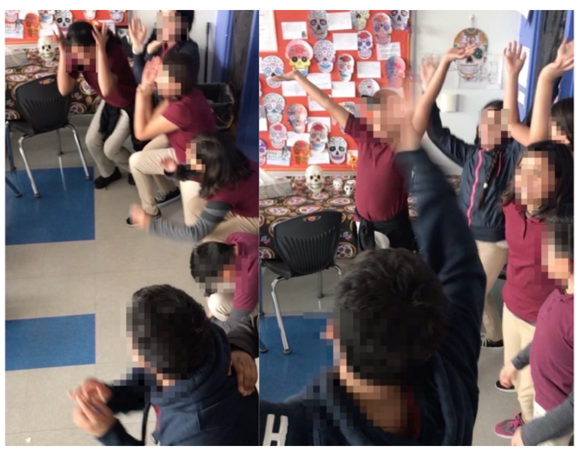
**Figure 34**

*Group 3 Represents Collection of Water in a Lake*

Leía continued to direct the group. "Ok, now we go into plants ~ ok now we get back into the line, we go down as if we were plants and then we're plants and we go like this." They crouched down, smiling and appearing excited through the affective effort in their bodies. They slowly rose up to standing, then burst into a laughter as they transitioned their upper bodies into a wide and spreading Shape with their feet and arms extended to either side and arms above their heads (Figure 35). When I asked what they were showing plants doing, Sandy made a meaningful connection with water collection–"because they're collecting the water. When there is precipitation the plant collected the water and it grew."

**Figure 35**

*Group 3 Represents Plants Collecting Water*

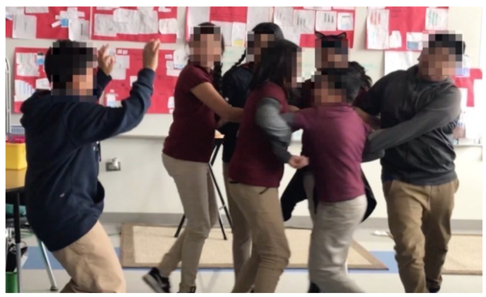


*Note.* The first image is of the students collecting water (as plants) and the second image shows them jumping up and springing outward (to represent plants blooming flowers).

Ms. Rosario called them up to share their performance and they assembled into their starting positions. They began by wiggling their hands and lowering their bodies with sustained Effort to slow their downward movements, showing rain. They got into their collection movement, their bodies wiggling from side to side on the ground while they and the audience giggled. Then, when they began to evaporate by rising upward, everyone except for Braylon formed a cloud by interlocking their arms and walking around in a circle. Braylon stood on the outside of the circle and made motions with his arms representing wind and rain (Figure 36) while the "cloud" performers laughed at his movements and sound effects.

**Figure 36**

*Braylon Represents Wind and Rain From Outside of the "Cloud"*

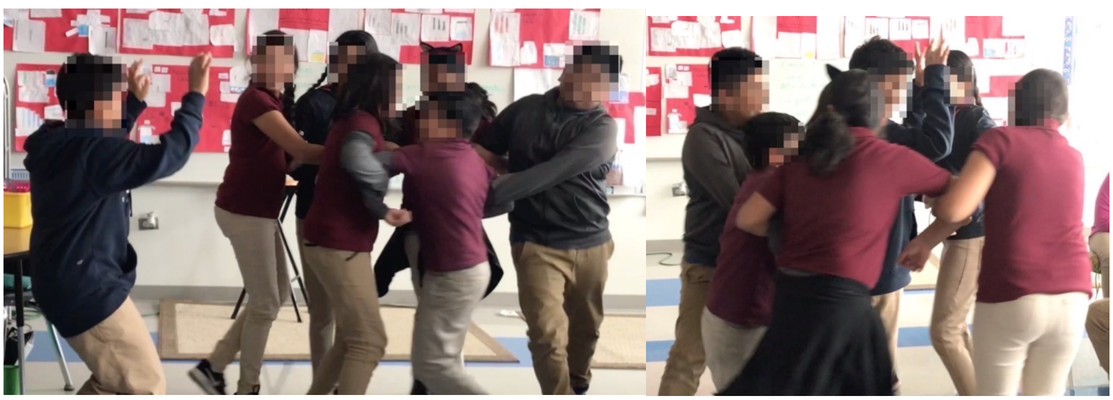


When they announced that they were done, Ms. Rosario quieted everyone down and began a reflection for the audience to process what they just saw and ask questions. Eric raised a question about where Braylon, representing wind and the rain, was located during the enactment. Eric asked, "The thing when they were forming the cloud, um, is Braylon doing wind and rain? Because how is rain going to happen if // because rain needs to be coming under the cloud." Ms. Rosario asked, "Eric, would you suggest the formation be a little different?" Ms. Rosario then walked them through making this revision that Eric suggested, urging Braylon to go inside the circle formed by the "cloud" performers. (Figure 37). The group tried it out and the audience liked this way better.

Braylon's spatial relationship to the cloud was revised, from being separate from the cloud to being a part of the cloud. Originally as wind and rain, or as rain moved by the wind, he was outside of the cloud, after the water left the cloud and was falling to the ground. In the revised model, as water inside the cloud, he was started falling out when water became too much to be held in the cloud. Both ways showed the intricacies of science ideas and the students' creative and meaningful ways of using their bodies and their movement in space to make sense and communicate science with each other.

**Figure 37**

*Before and After Eric's Revision*



The revision offered by Eric, of having Braylon go from outside the cloud to inside the cloud, is an example of the power of group reflection time at the end of the performance so that the audience can make sense of what just happened and participate in improving the model or bringing forward a different or nuanced idea. The performers and the audience benefited from this opportunity to think about the cloud and precipitation in different ways. By adjusting where Braylon stood, first outside then inside the cloud, the audience and performers engaged with multiple dimensions of precipitation as a science idea.

4. **<u>Illustration 8: "How Did All The Water Go Through All The Sand?"</u>**

Returning to the day when Ms. Rosario's class was planning out how water would move through sand (see Illustration 3), the sand group had just decided that they were going to let the water get through, but slowly. However, they did not coordinate this with the water group. When the groups said they were ready, Ms. Rosario announced, "It's raining," so the enactment could start. This cued the water group to walk toward the sand group, wiggling their fingers as they crossed the Space in a straight path, approaching the sand group's line (Figure 38).

**Figure 38**

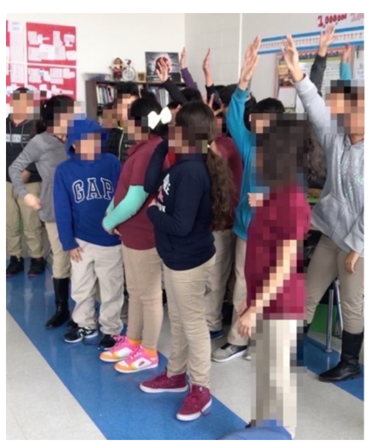
*The Water Group Approaches the Sand Group*

The water group passed between the sand group members very quickly. Even though the sand group planned to let the water soak in slowly, they did not have a chance to coordinate this with the water group, who excitedly walked between the sand performers without slowing down. Ms. Rosario saw this as an opportune time for reflection and revision, because it was clear that the two groups needed to know each other's intentions to make the enactment work. She asked the observers to talk about what they noticed. Leo, one of the observers, saw an issue with the enactment.

| | | |
|---|---|---|
| 1 | Leo: | How did all the water go through the sand and some of the water \| |
| 2 | Ms. Rosario: | Is it? |
| 3 | Leo: | Yeah cuz some of the water stays in the sand [he means during the experiment], but when they did it [just now] all the water went through. |
| 4 | Ms. Rosario: | Raise your hand if you're sand [sand raises their hand, all clustered at the front], raise your hand if you're water [water raises their hand, all clustered toward the back (see Figure 7)]. Listen to what he's saying. |
| 5 | Leo: | How did all the water go through all of the sand? |
| 6 | David: | Maybe because sand is so little even water can flow through there. It takes longer for water to flow through. It's kind of like gravel. You put a bunch of rocks in there and it flows fast. But sand is also made up of tiny little rocks, there's kind of space so that water can flow through. |
| 7 | Alan: | It gives me an idea about the beach. When water touches the sand it takes the water so I think the water goes through all the sand and gets to groundwater. |
| 8 | Dante: | I think we were being the top of the sand because the water was going really fast and we could not block them. |
| 9 | Ms. Rosario: | I like his point too, Leo's point. Could you repeat that? |
| 10 | Leo: | How did all the water go through all of the sand? |
| 11 | Ms. Rosario: | Because what did you observe about sand? |
| 12 | Leo: | Because when we did our experiment [referencing their experiment] part of the water stayed in the sand. |

**Figure 39**

*Water Group is Raising Their Hands*



Ms. Rosario asked the water and sand group to revise their enactment based on what the observers suggested. She gathered the sand group back together to talk with them before they did the enactment again.

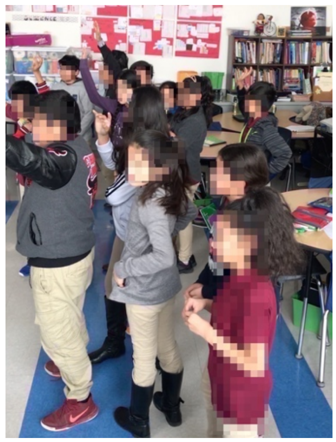
| | | |
|---|---|---|
| 13 | Ms. Rosario: | Come here let's talk. [she's gathering the sand group around her] |
| 14 | Javier: | Some of the people [the sand] should be in the back and some in the front. When they [the water] come they can be in the middle. That means that they're stuck in the middle and they cannot \| |
| 15 | Dante: | When the wave comes some of the people could move to the back. |

Now that they were revising, two different ideas came up. Javier's idea was, instead of forming a line, the sand group should be "in the back and some in the front" (unit 14), forming multiple layers. Dante's idea was a little different and possibly arose because of Alan' idea about what happens on the beach when a wave breaks on the sand (unit 7). Rather than positioning themselves initially in the front and the back, as Javier suggested, Dante thought some sand should move to the back with the water (unit 15) to show that the water was shifting it.

The chance to revise embodied performances through the reflection process was critical to making the science ideas clearer and more accurately represented. Leo challenged the way in which the groups were representing what he, and the rest of the class, had observed during their experiment. As he started transducing meanings across actual objects and body movements, he pushed the groups to both discuss and revise their initial movements to better capture ideas that emerged as the class reflected on the enacted model. The second time around, the water group started walking toward the sand. There was plenty of giggling as the sand made it harder to get through, resulting in a mix of sand and water. The water and sand groups were more mixed together (Figure 40) which was apparent when they were asked to raise their hands again to indicate whether they were representing water. The revision process afforded the opportunity for collective sense making among the performers and the audience.

**Figure 40**

*The Water Is Gone Through Different Layers of Sand*



*Note.* The water group (raising their hands) is more mixed with the sand group, rather than going completely through the sand group.

5. **<u>Illustration 9: "Water Grabs Dirt"</u>**

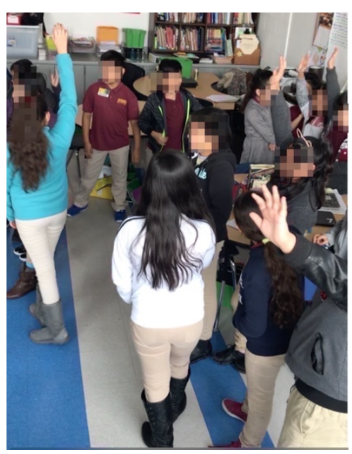
Directly following the sand enactment, the groups were reorganized into a soil group and a water group. In this enactment, the soil group barely let the water group pass, shifting their bodies in Space in ways that blocked the water group's path. It took much longer than in the previous enactment for the water to get through the line that the soil performers formed, but when the water got all the way through, all the soil performers were still at the top, in their line, and all of the water performers were in the back, having made it through. An idea for how to improve the enactment, to make it come out more like what they observed in the experiment, surfaced during the reflection:

1 Ms. Rosario: What do we think now? Somebody different, I keep hearing the same people. Abril!
2 Abril: I think that maybe a little of the dirt needs to go back because water grabs dirt.
3 Ms. Rosario: [smiles] Let’s try this really quick. I hope you were listening. Let’s try it. Ok, it’s raining. Think about what Abril just said.

Ms. Rosario was intentional on the dialogic nature of the reflection in her encouragement of more voices (unit 1). Abril was not afraid to offer a different idea. By referencing what happened in the experiment, she also connected the movement with what they observed, that “water grabs dirt” (unit 2). The performers were indeed listening, because several of the water performers now brought the soil performers along with them, to the back, or in the middle. When the different groups, water and soil, were now asked to raise their hands, it was clear that the water and soil were now more “mixed up” like the mud they had observed in their experiment (Figure 41).

**Figure 41**

*Water Mixes With Soil*



*Note.* Soil performers are raising their hands.

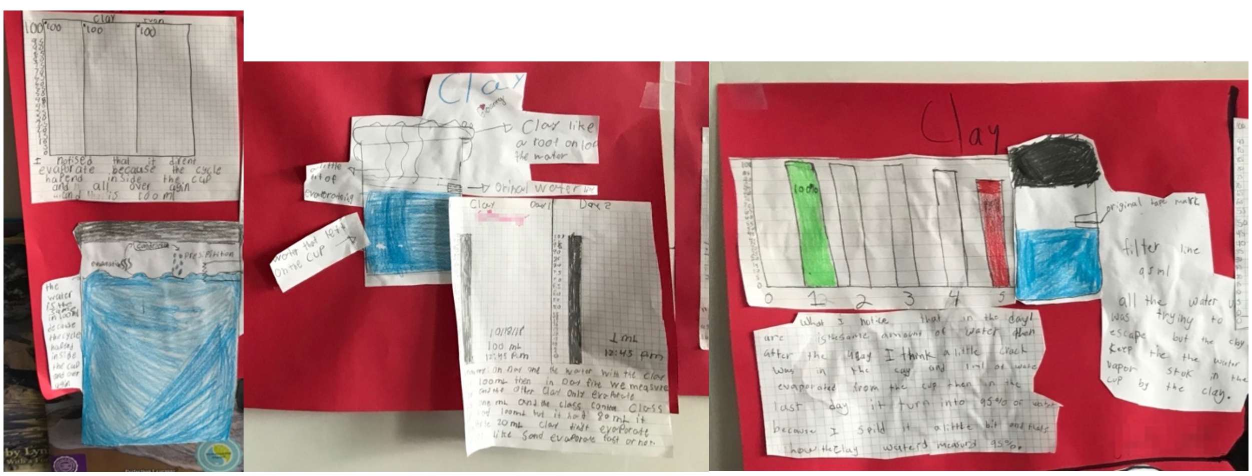
6. **<u>Illustration 10: "Too Forceful"</u>**

The next challenge that Ms. Rosario gave the students was to enact water poured onto clay. Several students asked if the girls could play the part of the clay and the boys, the water. A few of the boys including Leo, Oliver, and Braylon decided to be the audience.

A few days before, when children made their final posters for the experiment, they noted that the water line in the clay cup either did not change at all or lowered only slightly over the course of several days. Many, thus, came to the conclusion that the clay was a barrier that water could not pass through (Figure 42) unless there were cracks in the clay.

**Figure 42**

*Cropped Student Poster Photos Showing Only the Clay Observations*




*Note.* These photos show only the part of the posters that focused on the clay cup for each group. In each image the water is drawn at or near the original fill line and the clay is understood as a cover that does not let water vapor escape.

The two groups, water (the boys) and clay (the girls) huddled up to plan. The girls were excited and talked over each other while they came up with their ideas.

| | | |
|---|---|---|
| 1 | Leía: | Like two boys can [pass through]. |
| 2 | Mia: | Yeah, like two or three boys can. |
| 3 | Leía: | Like when there's cracks. |
| 4 | Carla: | Wait, guys, guys, guys. |
| 5 | Mia: | When I did the experiment a little bit of water passed [gestures with her thumb and pointer finger, joining them] |
| 6 | Carla: | Wait guys I have an idea. He [not sure who Carla refers to] said when there's holes it [the water] can pass through. |
| 7 | Leía: | What if he dives [smiling, puts her hands together in a diving motion]? What if he just dives in? |

As their speech and gestures indicated, the girls' plan was to allow just a few boys to pass through a "crack" in the clay (unit 3). Mia recalled that in the experiment, some water, in fact, did pass through a crack in the clay (unit 5) and Carla brought up the possibility of clay having "holes" (unit 6), but Leía wondered how exactly the boys would get through. She giggled when she wondered if some boys may "dive in" (unit 7). At this point, they began to assemble into a line, still working out their plan hurriedly while they interlocked their arms, and appeared quite excited to try it out.

Ms. Rosario quieted the room. There was plenty of palpable excitement from both groups. When they were calm and ready, Ms. Rosario said, "it's raining." Javier was one of the first to get to the line and when he realized he could not get through the "wall," as he called it, he called out, "Yay I cannot pass." Some of the boys saw that Leía and Mia, enacting the crack in the clay, were letting some boys through so they hurried over to them. Leía was counting, "one, two, three, four," to make sure they let through just a few boys, including Javier, Dante, Enzo, and Liam. Then right as Mateo was about to pass through, Leía and Mia close the "crack." At the end of the line, Alan and Eric snuck around the last girl in the line, Nicole.

| | | |
|---|---|---|
| 12 | Ms. Rosario: | Alright stop, stop. Water, raise your hand [the boys raise their hands. Six boys are on the other side of the girls and the rest of the boys did not get through]. Gentlemen who are observing, what do you think about where water is right now. You have any questions? What do you think, Oliver |
| 13 | Oliver: | I have a question. Why did a lot of water um came through. Because in my opinion maybe two or three raindrops should pass. |
| 14 | Leo: | I seen the part where Leía and Carla [he means Mia] like they broke apart right there and that's why a lot of water got through. |
| 15 | Ms. Rosario: | Ok I'm going to ask Leía and um who? Mia what happened? Why did you break apart? |
| 16 | Mia: | Because when like um we did the clay only like some drops got to pass not like a lot of water. |
| 17 | Ms. Rosario: | Ok only a few drops should pass, not a // I think Oliver was saying the same thing. One more time, let's try that again. |

Ms. Rosario asks the boys to raise their hand (unit 12) so that everyone could see where the water ended up. Oliver, from the audience, did not think it made sense for so many boys to get through because a crack in the clay would only allow a few drops to get through (unit 13). Leo noticed the same issue (unit 14) and Ms. Rosario asked the girls why they let some boys through (unit 15). Mia explained that they wanted to show that some drops of water could get through a crack in the clay (unit 16) but Ms. Rosario asks them to try it again (unit 17) to see if they could incorporate Oliver's revision. The girls exchanged some words but they were not audible to the camera.

Once they had set up for another try, Ms. Rosario said again, "It's raining." The girls must have decided that this time they would not let any of the boys pass through, because this time instead of letting a few boys through, they locked their arms tightly together with strong Effort, pushing back on the boys who were trying to get through. Enzo and Dante excitedly pushed their way through two different girls, Carla and Jessica, while these two girls were clearly trying to stop them. Ms. Rosario said, “Alright stop. Raise your hand if you’re water [Enzo and Dante were laughing and raising their hands from the back and the rest of the boys raise their hand in the front]. Ms. Rosario called on Braylon, from the audience, who impatiently wanted to say something.

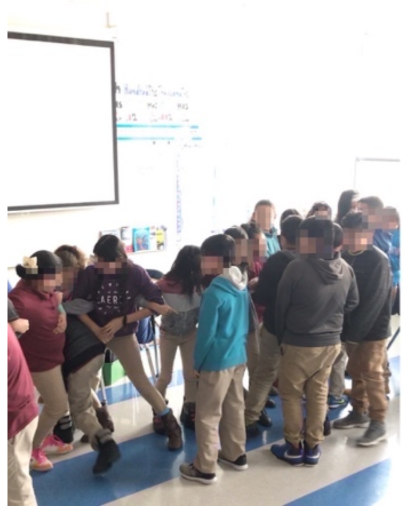
| | | |
|---|---|---|
| 18 | Braylon: | I have a question for Enzo. Why did he go through the people, like through the leg? |
| 19 | Ms. Rosario: | He looked like he forced himself through, right? That’s what I’m talking about friends. Ladies, did you want them to go through? |
| 20 | Students: | No. |
| 21 | Ms. Rosario: | That’s what I mean by being an active participant. And with your body act the part. If the girls are saying no I don’t want you to go through. It’s for a reason. They’re trying to point something out. So don’t force yourself through it. Because then it’s not really acting, it’s a game. We’re trying to have fun learning these concepts but if it gets out of control and we get hurt then we can’t really do that. We have to be active participants. |

Braylon wanted to know why the two boys forced their way through the two girls (unit 18) and his question revealed that he had a sense their actions were too playful and thus, not scientifically accurate. Ms. Rosario agreed with Braylon’s comment, and said that it seemed like there was too much forcing and not enough listening to one another (units 19 and 21). The first time, the girls allowed too much water through a crack in the clay, but they did not have a way of telling the boys they were not going to have a “crack” in this next iteration. In addition, the two boys were being playful rather than taking cues from the girls who were resisting their actions. Ms. Rosario reminded the whole group that this is about acting out the science, not turning enactments into a game (unit 21). The discussion continued after this, in which students continued to reason about the scientific ideas at hand.

22 Alan: In the experiment when we did the clay the water passed through.
23 Ms. Rosario: Does it?
24 Alan: When we had the cup with the holes in it.
25 Ms. Rosario: In your cup did the clay have any cracks? Were there any spaces in between to let the water pass through? You want to say something?
26 Oliver: Maybe Dante and Enzo did squeeze through because in real life if it did happen um // the water is weak, and um it doesn't have that much force to go through clay.
27 Leo: Unless there's a lot of water combined.
28 Ms. Rosario: So right, so are you hearing what they're // the point they're making? Wonderful point, right? If you're just one or two drops of water does it have that much force as opposed to or compared to what?
29 Leo: Like a wave.
30 Ms. Rosario: A wave, right? Is a wave |
31 Leo: Because a wave has power because there's a lot of um water combined.
32 Ms. Rosario: So I think what you're saying is the way they were acting // was how? #Too forceful or#
33 Leo: #Too forceful #
35 Oliver: Because I heard a scream.
36 Leo: Yeah.
37 Ms. Rosario: Yes. And that's why I addressed it too. I heard a scream too and I though people were going beyond acting.

Alan defended the actions of the boys trying to get through because in the experiment some of the water got through the clay (unit 22). Ms. Rosario's question was probably to remind the class that the clay really should not let any water pass through since the intention was to not have any cracks in the clay (unit 25). Oliver then offered an interesting justification of why they had to "squeeze through," which was because without extra force, a few drops of water would be too weak to pass through a crack in the clay. Leo, building on Oliver's point that there would need to be a force to get the water through the clay, suggested that perhaps a wave could get through clay (unit 31). Ms. Rosario and Leo agreed that this was too forceful. Oliver shared that he heard a scream (unit 35) which signaled to him that this pushing was "too forceful" and not what the girls had intended to show about clay.

**Figure 43**
*Water Performers Try to "Push Through" the Clay Performers*



This illustration demonstrated how important the dialogic reflection can be, in order to negotiate revision suggestions from the audience. Important scientific ideas surfaced in the reflection that helped the class further consider how clay is like a barrier and how much water should get through the crack in the clay as well as how much force small and large amounts of water have. They also reviewed the importance of listening to each other during enactments, not just to what was spoken, but also to body language.

BAS conversations with students a few weeks after this enactment revealed the importance of these dialogic reflections for identity work and knowledge construction. Mia reflected on the clay enactment in December, a few weeks after acting it out with her classmates. When they were planning the enactment, Mia wanted to show that a few drops of water could get through a crack in the clay. But when she looked back on the enactment a few weeks later, she thought about the clay a bit differently. I asked her to think about the enactment, "You were one of the girls holding the water back, right?" She responded, "When we were trying to test clay and see if water would pass through I saw that it was really strong. It held it there, it stayed. It doesn't really have pores like gravel, water can pass through [gravel] easily. But clay is really strong and just stayed there and didn't really do any movement." The animated way in which she talked about the clay was likely informed by having had the opportunity to embody it. I asked Mia if drama was helpful to her. She said, "Yeah like how things react together. And when you try to act it out, it's like // if I was actually a part of clay and I was just like acting like it // and depending on how it acts I'm guessing that's how you're supposed to react." For Mia, dramatic embodied performances allowed her to experience the phenomenon from the inside. By imagining she was "a part of clay" she was  imagining what clay would do and how it would "react" with water. These embodied performances were not a scripted dramatization but rather improvisation–a way to step into the process itself and explore what would happen.

The importance of the dialogic reflections was also noticed by the students themselves. During BAS conversations, several students mentioned the reflections as valuable to their learning. Javier articulated how he thought about the questions during the reflections. When I shared with him that I had noticed he asked a lot of questions in class he commented: "I do like to ask question but sometimes if I don't have a question to ask I think about the performance. Leo // he actually gave me a question last time. From that answer I got another question and that's why I raised my hand." Javier distinguished between asking questions aloud and quietly thinking about the performances. Rather than thinking of answers as an end, he thought of them as generative of new questions in collaboration with his peers. For Abril as well, the science vocabulary words were challenging to learn, but the questions raised in the reflections of embodied performances helped her understand them. When I asked Abril how embodied performances helped her, she replied, "For the vocabulary sometimes I do it alone and when we talk and say our questions, when they act it out and then we talk and say our questions, that helps me with the vocabulary and how does it mean each vocabulary. Precipitation. I didn't have an idea. When someone said that he was acting like it was raining." Yasmin also considered the questions during the reflections helpful to her science understandings and learning new vocabulary: "It [acting] helps me with the vocabulary words. The questions help. Why don't you show this in your enactment? Why don't you pull more of this to the part?" For Yasmin, the questions that others asked helped her think about ways to improve her group's performance. Dante, when asked if he felt like a scientist when he acted out the water cycle and aquifers, wrote that he did feel like a scientist "because I said a lot of questions and I was talking and feeling like a scientist." For Dante, asking questions and participating in discussions was what felt most scientific to him.

Reflections after embodied performances allowed time for theorizing and communicating ideas, thus expanding opportunities for students like Dante to feel like a scientist. For Abril and Yasmin, reflections were essential to connect the science vocabulary to the movement. For Javier, reflections were times when classmates could push each other's thinking in new ways because questions lead to answers which lead to more questions. For Mia, reflecting on her performance of clay led her to talk about the clay in the experiment with the embodied knowledge of imagining being clay. The reflections gave each student a chance to position themselves in different ways as science learners and expand their engagement with science.

## C. **Multiplicity of Embodied Performances Allowed The Audience to Engage in Multiple Interpretations and Identity Work**

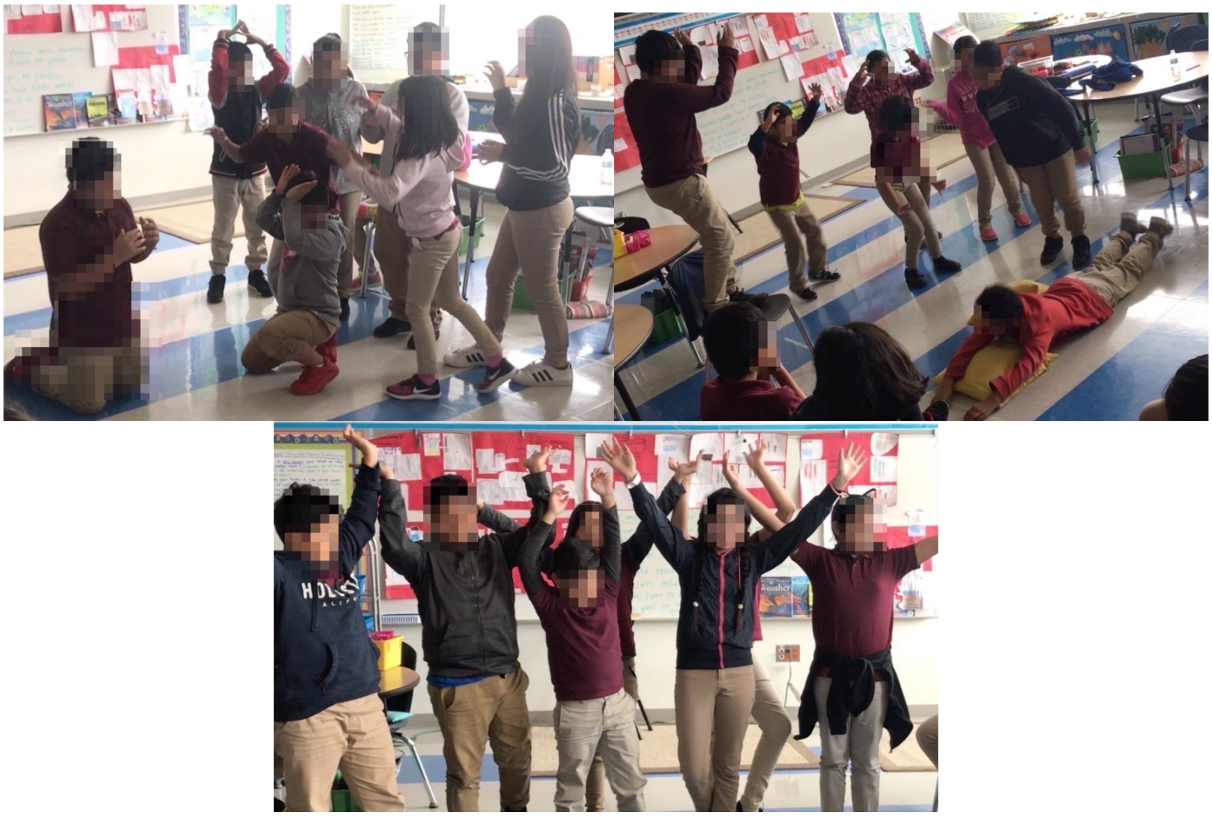
Children considered different aspects of the same phenomena by seeing classmates' multiple representations. In Ms. Rosario's classroom, models were produced in several different modes, including embodied performances, drawings and written language in notebooks, three dimensional models, and graphic representations on posters. In planning for embodied performances, groups considered semiotic choices that would best communicate their understandings. The audience then had the chance to reflect on the particular ideas foregrounded in the performance and also offer revisions. Embodied performances helped children think creatively about science ideas by helping them make connections to other ideas and come up with related examples. Several related but unique embodied performances offered a heightened level of engagement because many interpretations became possible and comparisons could be made across different performances. Each group's performance could not contain all ideas related to a particular concept, thus different embodied performances allowed multiple ideas to be considered collectively. As Javier said when asked how embodied performances helped him learn science, "I learned new things. I didn't see the same thing twice. I saw something new every time I saw a group pass."

### 1. **Illustration 11: Various Water Cycle Enactments**

The various water cycle enactments in early November gave children opportunities to think about the water cycle in multiple ways (Figure 44).

**Figure 44**

*Group 1, 2, and 3 Performances of the Water Cycle*



*Note.* From top to bottom and left to right images show enactments from group 1, 2, and 3 respectively.

All of the groups used low, medium, and high movement levels to enact the water cycle but there were noteworthy differences among the groups. Group 3 acted out the water cycle as a synchronized series of movements, which brought attention to the changes in the water cycle since everyone was doing the same movement at the same time. In Group 2's performance, each performer or pair of performers did their own distinct dance and started in order, which brought attention to the co-occurrence of the stages of the cycle. Group 2 also included the sun in their model, which the other groups did not do. Groups 1 and 3 included plants as integral parts of the cycle while Group 2 did not. Groups 1 and 2 did their movements repetitively, foregrounding the perpetual nature of the cycle while Group 3 went through the motions one time, foregrounding the order of the cycle. No one enactment could show everything important about the water cycle, but together, several groups enacting the same concept in different ways offered opportunities for expansive thinking.

For example, during the reflection following Group 1's performance, Javier, from the audience, got an idea from the way Group 1 enacted each part of the water cycle simultaneously that had not been raised in class before. He said, "The ~ I think the water cycle doesn't have a start. When it is evaporating it could also be raining." Javier realized something important about the water cycle that was afforded by the choice Group 1 made to do the motions simultaneously. This helped Javier realize there is no beginning and no end to the water cycle, but rather it is perpetual and all stages are happening at once. About a month later, when I asked Javier during the BAS conversation how the water cycle enactments helped, he brought this same idea up again: "It helped us because I didn't know about the water cycle never stopping." Javier did not only share this idea while watching the embodied performance of his classmates, but this idea was also a salient one for him long after that performance had taken place.

Not only was there a multiplicity of ideas across different performances, but also within the same performance, audience members had a multiplicity of interpretations. Here is an excerpt from the reflection that took place after Group 2's performance, described earlier in the findings, in which different children watching saw different ideas come through.

1 Ms. Rosario: Let's talk about what we did see. Let's see. Go ahead [to Leo].
2 Leo: Ok, Oliver was the sun and the pillow was ~ the heat. So that's when he threw the pillow. Then he [meaning Javier] started moving, como loco [laughter erupts]. And the water was heating up. And then I lost him [Javier].

3 Leía: I was going to say Javier was the water.
4 Ms. Rosario: Anything else?
5 Alan: What Javier did made sense.
6 Ms. Rosario: We're going to see it again because we have time. We'll make sense of it.
7 Alan: No, like it did make sense. Because Javier did that because when the molecules start like to move a lot when the water is being heated // you showed us that // you showed us that sometimes // when you told us when you put hot water in the cup.
8 Ms. Rosario: The video that we saw?
9 Alan: When there's hot water, the molecules start to wiggle and circling around.

Leo and Leía could see that Javier was acting out a wavy body of water, at the macro-level, to represent the collection stage of the cycle (units 2 and 3), but Alan saw something different from the same performance. Alan was reminded of the micro-level of the water molecules (units 7 and 9). Even though Group 2 did not intend to enact the molecular level, for Alan in the audience, this is what the enactment helped him think about. The same performance offered multiple ways to interpret what was happening. The reflection time helped bring these different ideas into the collective space where they could be shared and reflected on further by everyone. The reflection continued.

10 Leo: Why is Dante running in place?
11 Dante: Because when air moves clouds you can see them and they're super // they're really steady and I've seen clouds sometimes moving with air in that direction. So, I was moving because it (the air) was moving…

In Leo's group (Group 1) the clouds stayed in place so his question of why the clouds in Group 2's performance were moving showed comparison across enactments. Leo' question (unit 10) gave Dante the opportunity to explain how he was thinking about the clouds, as both forming through condensation and moving with the wind (unit 11).

2. **<u>Illustration 12: Comparing Aquifer Enactments</u>**

At the beginning of December, Ms. Rosario's class was learning about aquifers, groundwater, and the water table. It was at this point in the school year when the class began explicitly grappling with socio-scientific issues, such as water pollution and conservation. To start thinking about these issues of how water pollution and scarcity affect human populations, they started exploring how fresh water collects underground in aquifers, both confined and unconfined, and how people tap into these naturally filtered water sources. They started by drawing diagrams of aquifers in table groups, using internet research to guide their drawings (Figure 45). Each table group shared the Chromebooks that the class had just received as a gift and they were excited to use them for the first time. Ms. Rosario had also shown them videos about aquifers that explained how water collected underground between cracks in the spaces between rocks.

**Figure 45**

*Examples of Students' Aquifer Diagrams*

Later that week, after they researched aquifers and made their diagrams, each table built a physical model of an aquifer using earth materials, including soil, sand, gravel, and clay. They could also bring in grass, dirt, and any other ground material they could find. Each plastic container had a soap dispenser as a pump (Figure 46).

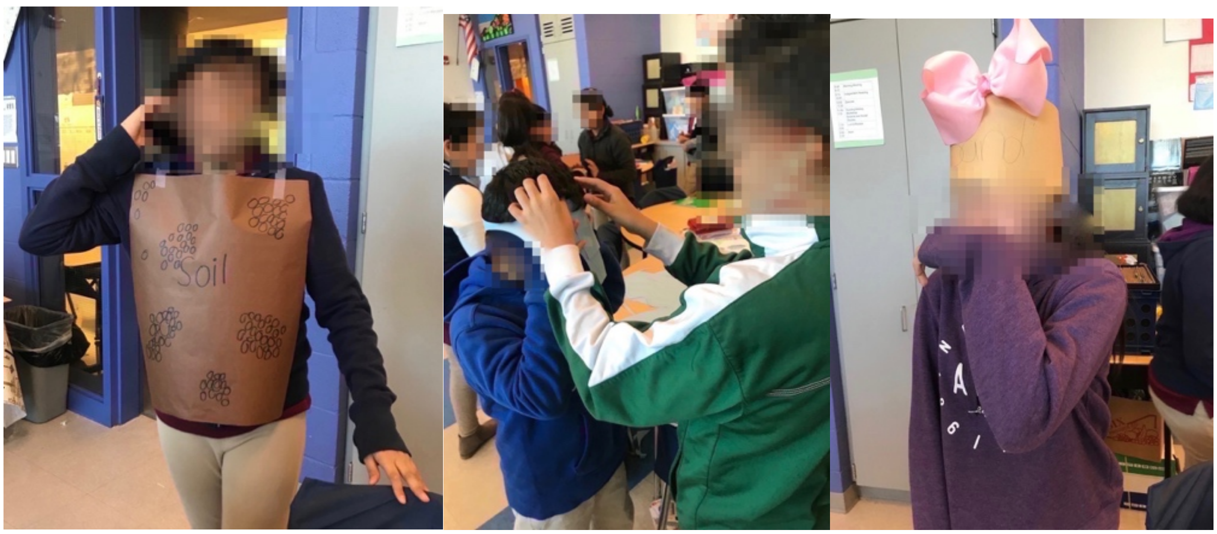
**Figure 46**

*Models of Aquifers*

Ms. Rosario put two tables together forming larger groups of 6-8 students. She asked each of the larger groups to use their diagrams to create an embodied performance of an aquifer, either confined or unconfined. The groups began by talking about what they could do to show an aquifer with their bodies. It was not until one group started to ask for construction paper and other materials that each of the groups appeared to get excited about using materials as part of their embodied performances. Soon Ms. Rosario went to get butcher paper and large pieces of construction paper, which all of the groups were now asking for. They began making costumes and hats out of the paper to represent different layers of earth materials (Figure 47). One group drew small pebbles on brown paper to represent soil and gravel, while others cut out and wrapped labeled hats around their heads. The whole class became busy in productive activity, creating material artifacts to infuse more meaning in their embodied performances, and there was palpable energy, excitement, and joy present in the room.

**Figure 47**

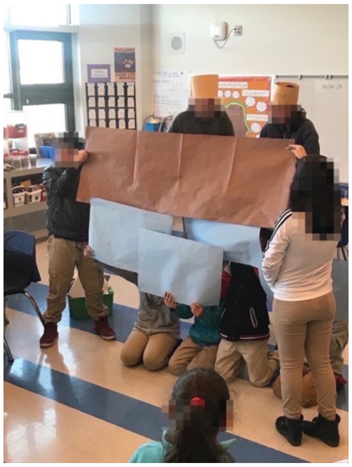
*Examples of Props and Costumes*



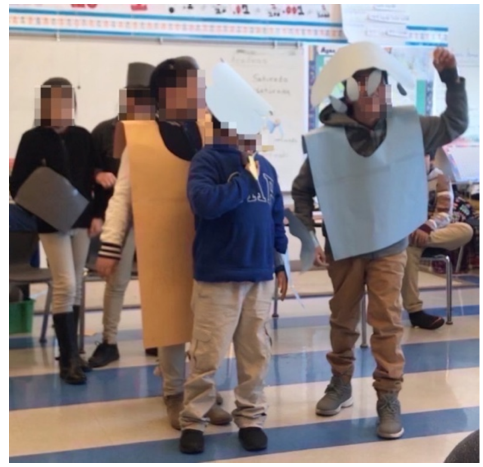

After they planned four different embodied performances over the course of several days, they performed them for each other. Each performance ended up highlighting different ideas about aquifers, which no one group could have done in a single performance (Figure 48).

**Figure 48**

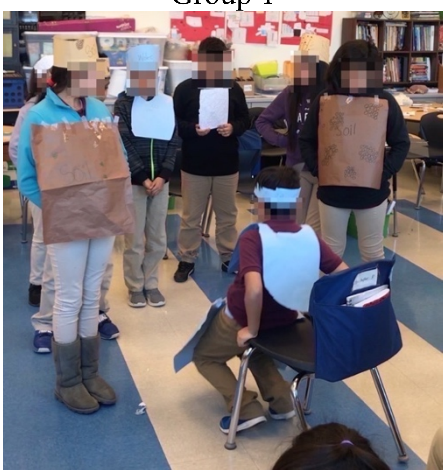
*Four Different Performances of Aquifers*



Group 1



Group 2



Group 3

Group 4

Group 1, having performed already last week, tried it again. Ms. Rosario had asked them to put some movement in their performance, which the previous week was more like a still *tableau*. They used large, horizontal pieces of butcher paper to emphasize the layers of earth materials surrounding aquifers. Nicole and another student stretched a large piece of brown paper that represented the clay layer, while Yasmin and Mateo, standing on chairs so they would be above the clay, wore tan colored headbands to represent the sand level. The overall Shape they created was that of a still wall, as if they were representing a cross-section of an aquifer with horizontal layers in Space. The water underneath these layers was represented by three students, each holding a piece of blue construction paper, moving it slightly to resemble water. David, holding his blue paper, stood up while moving the paper upward, behind the brown paper, to show that it was coming out of the aquifer. With the exception of the wiggling water and David's brief movement, which they added since the previous week, their performance was, for the most part, still motionless. During reflection time, ideas were further explored as additional movement was discussed.

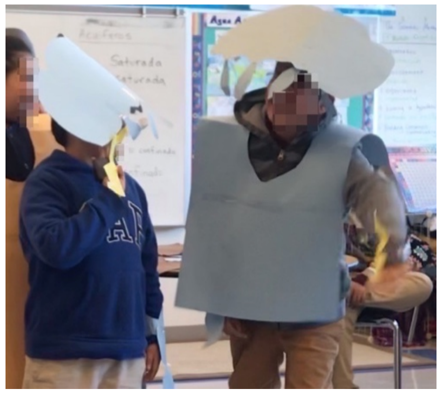
| | | |
|---|---|---|
| 1 | Ms. Rosario: | Do we notice anything new this time? |
| 2 | Leo: | They pumped the water. |
| 3 | Ms. Rosario: | The water is now == Show us how that happened. So what did you do with your movement? So what happens? Mateo, I think you need to do something. What are you Mateo? |
| 4 | Mateo: | A pump. |
| 5 | Ms. Rosario: | Don't tell us, show us. Show us. What is a pump, how does it happen? Do you notice what they did different this time? Alan what did you notice? |
| 6 | Alan: | That like he // like the video we saw the // when we ~ water // I can't remember what it said // like when we do something to groundwater there's no more groundwater. I forgot. |
| 7 | Ms. Rosario: | You're saying there is no more groundwater. What makes you think that? |
| 8 | Alan: | He [Mateo] took the water so I think there was no more groundwater. |
| 9 | Ms. Rosario: | What caused that? Is it clear? |
| 10 | Leo: | There's a pump now? |
| 11 | Ms. Rosario: | What's the pump doing? |
| 12 | Leo: | Sucking up all the water. |
| 13 | Ms. Rosario: | Does anyone have a suggestion for this group? |

Ms. Rosario encouraged them to show the movement of what they were representing (units 3 and 5). The lack of movement may have contributed to Alan' confusion about what happened in the enactment (unit 6). Leo was able to extrapolate what the pump was doing and what the enactment was trying to show (unit 12). Even though this enactment could have benefited from another revision, the class was still able to notice the pump and think about the role the pump plays in an aquifer "sucking up" the water and possibly drying out the aquifer (unit 8).

Group 2 showed the layers of the aquifer as Group 1 did, but instead of the layers stacked vertically, they showed the layers from front to back. Their emphasis was more on the water than on the earth materials. Javier and Dante, acting out the water, wore costume pieces or held props for each stage of the water cycle. They made cloud headbands with the shapes of raindrops cut underneath the clouds and lightning wristbands. Javier's punching gesture and sound effects, complete with his lightning wristband, signified rain and lightning (Figure 49). This group was clearly emphasizing the rainwater that replenishes aquifers, so they brought the water cycle into their performance, with Dante and Javier acting out precipitation, traveling back through the layers, then evaporating, which they showed by raising their forearms which had long strips of blue paper taped to them in an upward direction. Javier and Dante were wearing cloud headbands with raindrops. Group 2 did a repeated sequence of showing evaporating, forming clouds, raining, then going through sand slowly, then through gravel quickly, then stopping at clay. They did this several times to show that aquifers are interconnected with the water cycle.

**Figure 49**

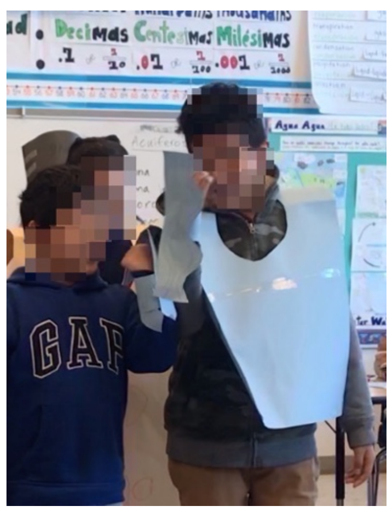
*Group 2's Aquifer Enactment*



Javier and Dante each taped a blue strip of construction paper on their forearms and during the evaporation stage would raise their forearms so that the audience could see this strip of paper going in a vertical orientation (Figure 50).

**Figure 50**

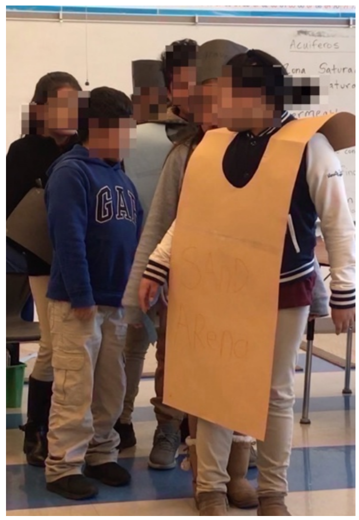
*Dante and Javier Represent Rain and Evaporation*




Jessica wore brown paper wrapped around her body with a hole cut out for her head and wrote SAND ARENA, to represent sand, and Lola's black headband had the word GRAVEL written on it. Valery, wearing a black sign, and Camila, wearing a black headband, were the clay at the very back, and the water stopped at them. (Figure 51) to signify that clay is a barrier.

**Figure 51**

*Group 2 Represents Rainwater Soaking Through Sand and Gravel*



*Note.* The words “Sand” and “Arena” are on Jessica’s costume and the word “Gravel” is on Lola’s hat.

At the end of their third repetition, Ms. Rosario asked if they were done and a class reflection began.

1 Alan: I think Dante and Javier are the water. They’re going slow because like the water is going through sand [Jessica] and gravel [Lola] and they cannot pass um the clay [Valery and Camila].

…

2 Enzo: I see they first are in that layer in the middle of the clay and the sand. Then they got on the head things, the clouds, and went back again and water was going in through the sand.

…

3 Ms. Rosario: They went through sand and then they stopped at clay. But you noticed Enzo that they began there. Is that true Javier and Dante? What process did you go through to show that?
4 Javier: We were doing unconfined. Because unconfined means that it could evaporate and confined means that it gets stuck there and then gets older and older.
5 Dante: Can I say something? That when we went through gravel we were walking really fast.
6 Ms. Rosario: Quickly, yes, when you got to gravel you made a turn because behind you they stopped at clay and turned around. The audience did notice // everyone raise your hand if you noticed they moved slowly through sand and then they moved quickly.

During the BAS conversation mid-year, I asked Mia which students in other groups helped her understand aquifers and she responded, “Dante and Javier, they were doing the rain and then they went back slowly.” Their variance in movement through the layers of the aquifer, fast through gravel and slow through sand, helped her understand more about how groundwater filters through different earth materials. Whereas Group 1’s performance helped the audience consider the role of the pump in an aquifer, Group 2 focused the audience’s attention more on the process of recharging the aquifer. The movement in Group 2 helped the audience see that an aquifer is not just a thing that exists but is also a *process*. Alan and Enzo, both in the audience, picked up key elements of the process of unconfined aquifers from watching the group’s movements. Alan picked up on the process of the rain going through the sand and gravel but not being able to penetrate the clay (unit 1) and Enzo noticed the cyclicality of the enactment (unit 2), the water going to the middle layer and then the process cycling over again. In the middle of the performance, Dante got the idea to go slow through the sand and quickly through the gravel, and right in the middle of the performance we can see Dante making this suggestion to Javier, who then adjusted his movements to reflect Dante’s new idea. When comparing this performance, which included the dynamic process of aquifers, with the previous performance, in which the performers represented the diagram with very little movement, it is clear that there was more meaning making possible during the reflection of this second performance.

Group 3 enacted a quite different way that an aquifer can be recharged. By using a chair to represent a mountain, a student, wearing blue paper and a sign with “Baby Water” written on it, was sitting on a chair. Enzo, wearing a sign with “Daddy Water” written on it, was standing in the center of a circle formed by Leía, the sand, Braylon, the gravel, and Sandy and Abril, the soil. The student representing “Baby water” then slid off the chair and locked arms with “Daddy water” while walking in a circle surrounded by those performing the earth materials  representing the “mixing” of the old and the new water within the aquifer (Figure 52).

**Figure 52**

*Group 3 Represents An Aquifer Forming From Run-Off*

*Note.* In chronological order from top to bottom and left to right. The images show Group 3’s representation of water “sliding” down the hill and forming an aquifer at the base of the hill.

During the reflection, it was clear that the audience was confused about what the chair represented and why “Baby water” was sliding off the chair. This idea, of water running off or sliding into an aquifer, was something new to consider and took time to develop during the reflection.

| | | |
|---|---|---|
| 1 | Javier: | The chair is a cloud and he's like raining. |
| 2 | Ms. Rosario: | Is that true [she asked the student representing "Baby water"]? Is that what you're doing? He's a cloud? [Baby water], what is your action, your motion from the chair. Look at how he's coming off the chair. Do it again. We're thinking about // maybe a science vocabulary word? |
| 3 | Leo: | I think he's infiltrating. |
| 4 | Dante: | Can I say what I see? I think the chair is a cloud and the rain falling so he just fell down on his knees. |
| 5 | Ms. Rosario: | So somebody thinks he's rain from a cloud to infiltrate into the aquifer. Is that true? |
| 6 | Performers: | No |
| 7 | Ms. Rosario: | I know, yes? How else can an aquifer recharge? Look at where he's sitting. He's telling you he's not a cloud. |
| 8 | Ms. Rosario: | [Baby Water], what are you acting as, tell us? What are you trying to be from the chair? |
| 9 | … | |
| 10 | Ms. Rosario: | Why? How does water slide [referring to what the student said]? From where? |
| 11 | Audience: | #A mountain?# |
| 12 | Ms. Rosario: | From the side of a mountain. What do we call that? |
| 13 | Leo: | Run-off. |
| 14 | Ms. Rosario: | Yes. Right? Show us again, how are you run off? So it's not coming directly from a cloud, it's coming from == |
| 15 | Audience: | The side of a mountain. |

Although the audience was unsure at first about why the student representing "Baby water" was sliding off the chair, they came to think about the idea of "run-off" after many repetitions and time devoted to unpacking this new concept. The idea of the "baby" water mixing with the "daddy" water led to a great deal of giggling in the performing group and in the audience as well. Ms. Rosario recalled later that selecting that particular student to be the "baby" water was consistent with social interactions other students had had with that students several times in the classroom. Mia, from the audience, reflected on this enactment during our BAS conversation when I asked her which enactment stood out to her as helpful. "Table 2 [Group 3] I remember that like water recharges. Some water recharges and some water just stays there." For Mia, the new water regenerating the aquifer and the water that stays in the aquifer were made memorable perhaps because of the visual image and subsequent extended discussion of the "baby water" and the "daddy water."

Group 4 engaged with the idea of the saturated zone just beneath the water table in their enactment. Group 4 planned their enactment by using one of the tables in the classroom to actually represent the water table. Two students, including Mia, were under the table showing with their props and movement that they were representing groundwater (Figure 53).

**Figure 53**

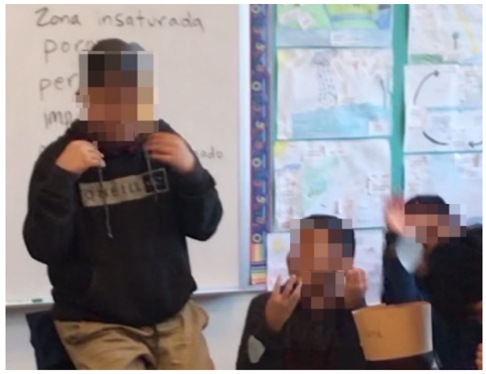
*Group 4's Representation of Groundwater*

*Note.* The group uses the physical table as a representation of the "water table" and as the rainwater continues, the water under the table rises above the table.

Manuel, Alan, and Eric, with the help of their props, movements, and sound effects, represent precipitation (Figure 54).

**Figure 54**

*Group 4's Representation of Precipitation*




*Note.* Not shown in this image is that the performers are behind the table with the water performers underneath it (Figure 53).

Crouching behind the table were the performers representing earth materials such as sand and soil. Oliver and Leo represented the sand and soil and their positioning above the water table (Figure 55).

**Figure 55**

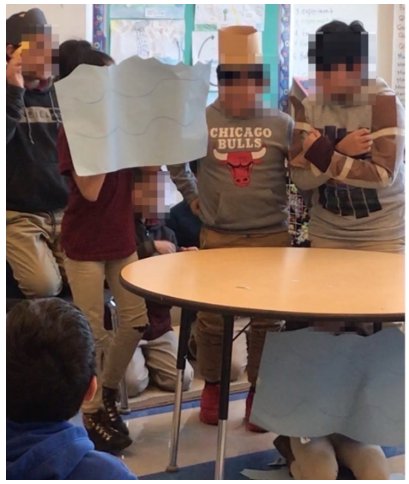
*Group 4 Represent Sand and Soil Above the "Water Table"*

Manuel made sound effects and movements he had developed for precipitation, which involved flicking the lightning rods on his hat with his fingers and making sounds, "BER-AH

BOOM!” The groundwater began to rise up above the water table, which they represented by one of the students under the table rising up to standing, shifting the paper representing the water above the table, and Mia, the other student representing the water, staying below the table (Figure 56). When I asked Mia what helped her understand groundwater from her enactment during the BAS conversation, she said, “It helped me because I saw that there is actually a water table and water is supposed to stay under that and if it flows up it actually makes a lake.” The concreteness of the physical table helped Mia make sense of the abstractness of the “water table” and its function in separating groundwater from lakes. She also commented that she did not know about groundwater before they learned about it in class. “Water could also turn into snow and it could also be like groundwater which I didn’t know before. When I walk, I know that water is under me and it’s pretty weird.” She grappled with the idea of having water burrowed away in earth that she did not know about and the embodied performance had supported her meaning around that idea. She was also aware that she struck a balance between leading and listening to others: “In the aquifer enactment I was giving a lot of ideas but I was also listening to other peoples’ ideas.” She added that the ideas she was contributing, were generated while talking with her family: “I talked to my mom about it and she said there is water under. She knew about it. She told me that // all about clay and all the things that’s under.” Mia’s agentic science identity was emerging. She learned that people’s own actions on a small scale could bring about change. She shared ideas she was learning at school with her little sister: “I told her not to waste a lot of water. I told her that there was groundwater and that a lot of people use it and it // if we use it too much there won’t be a lot of water left. She was like ‘oh ok’ and she tried not to use a lot of water. She was cleaning her teeth and she turned it off when she wasn’t using it.”

**Figure 56**

*Group 4 Represents Water Rising Above the "Water Table"*




Strong science and performing identities were evident in others in this group as well, as seen through their commitments to experience and embody the part they played. For example, Manuel, adding sound effects and tapping the lightning bolts on his headband, directed his gaze at his classmates and increased his commitment to his sounds and movements as he heard their laughter. Leo, as he usually did, led his group and indicated when it was time to start and stop the performance.

At this point they gestured that they were finished and the group reflection began.

| | | |
|---|---|---|
| 1 | Dante: | Can I say what I see. Like they enact the rain and then I saw her going up [gestures upward movement with both hands] because maybe it was filling up. |
| 2 | Ms. Rosario: | What's filling up? |
| 3 | Dante: | The groundwater. |
| 4 | Ms. Rosario: | And then it formed a == |
| 5 | Dante: | A lake. |
| 6 | Ms. Rosario: | Did you see that? How // can you start again, when you were first groundwater? Show us your position. And then as it's raining, go ahead show what's starting to form. So then, what's this, friends? What's she forming? |
| 7 | S: | Evaporation. |

8 Students: Lake.
9 Ms. Rosario: A lake, she forms a lake above the surface of the earth. And we saw that with our models, right?

Dante, consistent in his enthusiasm to share his ideas, noticed that one of the girls under the table stood up with her blue paper (unit 1). Ms. Rosario helped Dante articulate what he noticed (units 2, 4, and 6). When someone in the audience thought they were showing evaporation (unit 7), several audience members said that they thought the student who rose up holding the blue paper was representing a lake forming (unit 8).

The first group, despite the lack of physical movement, afforded the audience the opportunity to consider the role that the pump plays in an aquifer. The second group afforded the audience a chance to think about the water cycle and its relation to unconfined aquifers, as well as the difference in speed at which water can pass through sand and gravel while stopped by the clay. The third group represented an entirely different idea, that water can replenish aquifers by sliding down a mountain as well as by precipitation. The fourth group showed that as groundwater fills up the aquifer, it could rise resulting in a lake above the surface. This group provided the opportunity to think about the water table, at the top of the saturated zone, a particular part of an aquifer rather than the whole aquifer.

These embodied performances demonstrated the multiplicity of ideas that resulted from the different performances that the groups created on the same concept. Different ideas surfaced in each enactment, and, through reflection, helped expand performers' and audience's understandings. When I asked Javier about his aquifer enactment, he said, "I was water. Something I observed was everyone did something different. Me and Dante were water when we went through sand we went slow and in gravel we went fast." David also acknowledged the importance of seeing multiple representations. He said about his classmates, "They all have different ideas so you can understand how each one is." Yasmin, commenting on whether it helped her to see different enactments, said, "Watching my classmates' performances helped me learn more about the water cycle and aquifers because every performance was different so I could understand it." The difference Yasmin, Javier, and David talk about is the essence of multiplicity. Each water cycle and aquifer performance made use of different movements, timings, levels, and arrangements that brought particular ideas to the forefront while backgrounding other ideas. Multiplicity extended to drawings in their notebooks that the students shared with one another, posters around the classroom that offered different visuals and diagrams, and aquifers that small groups built, all similar in which materials they used but unique in how they layered and arranged their materials. Any one enactment could not contain all of the different and important ideas when building a science concept. By allowing multiple groups to work on their own versions and in their own ways, and then coming together as a whole class to reflect on each one, the multiplicity of ideas was not only enabled, but also recognized as instrumental in meaning making and identity construction. Whenever children are offered multiple ways of showing their understandings and open-ended opportunities to develop and share ideas in multimodal ways, a multiplicity of ideas, relationships, and identities become possible.

## D. Perspective-Taking Engaged Children in Knowledge Construction and Agentic Identities

Taking on different perspectives is drama's special affordance. In the case of Ms. Rosario's classroom, children tried on other viewpoints, whether in oral discussions or through embodied performances. Through embodied work, children took on other perspectives different from their own, whether these were perspectives of people, entities, or processes, thus creating opportunities for ideational, social, and affective responses to scientific ideas. Inside the pipes in Flint, children passed through as water and chlorine, while bits of black paper, representing lead, sprinkled over them on their path. They felt like they were becoming the water that was getting polluted, thus, seeing water from a new perspective. During the BAS conversation mid-year, Leo said, “by showing our enactments we were trying to see how water acts.” The value of this “trying to see” by becoming something different from who someone is was echoed by other children. For instance, I asked Yasmin if acting was helpful to her science learning and she responded, “Yes because you are not going to understand evaporation with pictures but if you act then you can understand how water evaporates.” By acting out the entity itself, embodying the water or the sand or the clay, the children developed deeper understandings by experiencing and even feeling like the entity itself. Dante wrote at the end of the year that learning science through drama was helpful because, “like you somehow feel if you are water or evaporation how does it work.” Similarly, Leo said, “The videos doesn’t really show how water acts,” For Leo, while stepping into the role of the water and acting like he imagined the water would act, he experienced a perspective that a video could not provide.

The children saw scientific entities differently by embodying them. The children also tried on different peoples’ perspectives in order to explore a problem from a different point of view. Children embodied the government officials in Flint, exploring the officials’ perspective of how to economically benefit by switching the water source even though and, perhaps importantly because, the children knew what they did was “wrong.” The same children days before had expressed a range of affective responses, from disbelief, to anger, to critical consciousness, at what the government did to the people of Flint by switching the water source. Not only did acting out this egregious example of injustice, from various points of view, help students learn ideas, but they also did important identity work through these experiences, developing their agentic selves as young people willing to act to bring about change. Drama offered opportunities for constructing science knowledge, including critical consciousness of policies that affect the health of citizens, and agentic identities that expressed caring and advocacy. Although affect often is absent from children's experiences in science, the embodying that these children were allowed to create and experience in science class provided them important opportunities for affective ways of experiencing science learning.

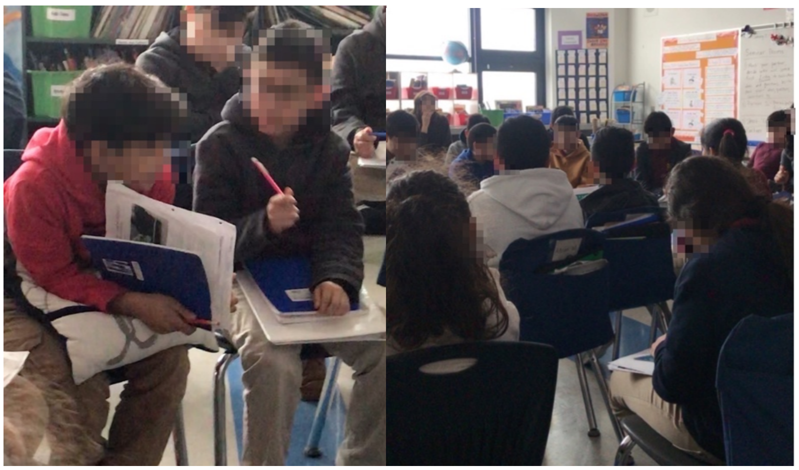
### 1. **<u>Illustration 13: Socratic Seminar on Flint</u>**

When the class returned after winter break, they began to learn about water pollution. In particular, they read articles and watched various films about the Flint, MI water crisis, including the Nova special, *Poisoned Water,* to which the class had a strong collective emotional response to the injustices portrayed in the film. After viewing the film and reading a number of articles, Ms. Rosario began Socratic Seminars, a classroom structure in which an inner circle had a discussion drawing heavily on texts and the film as resources, while the outer circle had these same texts in hand but could not participate in the discussion until it was their turn to switch to the inner circle (Figure 57). In a Socratic Seminar, the teacher tries to allow the students to respond to each other as much as possible, without the teacher's mediation unless it is needed.

Today was the third Socratic Seminar, and with the lead pollution articles in hand, the class was seated on chairs arranged in an inner circle and in outer circle. The students spoke in English and Spanish as they discussed ideas while Ms. Rosario encouraged as many students as possible to participate. The Socratic Seminar started out with just a few outspoken members of the class involved in the discussion.

**Figure 57**

*Socratic Seminar on Flint Water Crisis*



*Note.* The image to the left shows Ethan (left) and Alan (right) leaning forward, engaged with their whole bodies in the discussion. The image to the right shows the inner and outer circle of the Socratic Seminar.

Ethan, who had presented himself as outgoing all year, was especially charismatic today, and began the seminar by asking, “Do you think any officials from the EPA went to jail or were charged?” There were some giggles as the others gazed around the circle, some at their various texts, waiting for someone to respond. David, perhaps annoyed by the silence and eager to get a conversation going, said, “It doesn’t have to be right or wrong it’s just your opinion. So what do you think?” By the silence and shifting eyes of the others, it was clear that several students felt uncomfortable talking in this format or responding to this particular question. Enzo took this opportunity to ask a new question to the group: “Why did the government make this bad choice for the first time, switching the water?" When David questioned whether this really was the first time, some students read this as a challenge to Enzo and made an "Oooh" sound. Ms. Rosario said, "We're trying to get down to the bottom of truth here. It's not a challenge to each other, we want to see if we're all understanding the text." The class quieted down, and the following dialogue began.

| | | |
|---|---|---|
| 1 | Ethan: | The government thinks he was doing a good choice but it wasn't a good choice. The place where they cleaned the water wasn't used for 50 years and they didn't put the corrosion control. |
| 2 | David: | Why did they // didn't they communicate with this? |
| 3 | Enzo: | The government told her // they were sending water filters to Flint and they told her that they // removed some of the lead from the water. |
| 4 | David: | They lied? They lied? |
| 5 | Enzo: | Yeah, they lied about that. |
| 6 | Ethan: | I have an opinion about that. They lied about a whole bunch of things. They lied about the water being safe. And probably the water that the governor was drinking on the television was like clean water, they just grabbed a cup and a water bottle and put the water bottle water in the cup. |
| 7 | Alan: | He // even didn't even say nothing about it. He didn't explain nothing about it. He didn't explain that he had rashes or something like that. |
| 8 | Ethan: | Yeah, and if the governor wanted to show that the water was clean he should have grabbed a cup recorded him going to a house and opening the sink and filling up the cup and he drinking it. Then we could see there was lead on it. |
| 9 | David: | Also what's it called // It's not the mayor's job to drink peoples' // drink water to see if it's good or not. |
| 10 | Ethan: | That's a fact. |
| 11 | Alan: | Well, the government made that problem. Because he just wanted the money. That's it. Because he // it said in the movie that he was just trying to save money. |

Not only did the speakers' affective responses become more and more intensified, as seen and felt through their increasing pace of speaking and more forceful expressiveness in their faces, the listeners focused more quiet attention on what was being said and their body positions shifted a bit more forward in their chairs. David and Alan wondered whether the government would actually lie to the people (units 2 and 4) but Ethan and Enzo were not surprised at all by this (units 3, 5, and 6), considering various lies that had surfaced. Ethan positioned himself as a critical thinker able to see how powerful interests were operating without the peoples' interests in mind (units 6 and 8). Alan and David began to shift toward a more critical perspective after hearing Enzo and Ethan's points. David agreed with Ethan that the mayor misled the people (unit 9) and Alan remembered from the film that the government was driven by the pursuit of money over the people's health (unit 11).

Lola joined the conversation at this point. Lola had entered the class recently, mid-year, after crossing the border from Mexico to the US to live with her relatives. Ms. Rosario often encouraged her to speak in Spanish and marveled at how well she was adjusting and at how many relationships she was forming with the other children. Those who usually spoke in English seamlessly continued the conversation in Spanish after she asked her question, signaling to Lola that they valued her contribution and the language in which it was spoken.

| | | |
|---|---|---|
| 12 | Lola: | ~Um ~ salvaron a los niños que están enfermos? [Did they [the government] save all of the children that were sick?] |
| 13 | Students: | No! |
| 14 | Lola: | Para poder ~um ~ // para que ellos no tuvieran un comportamiento malo y no tuvieran que las personas adultas se enfermen? [To be able to ~ for them to not have a bad behavior and so they would not get the adults sick? |
| 15 | Oliver: | Yo creo que sí ~ pero trataban pero no podían [I think yes ~ but they tried but they couldn't because] |
| 16 | Ethan: | Solo ~ lo que pasó es que ~ cuando se mete al cuerpo ya no se puede sacar el // ya va estar en todo el hueso ~ se va a toda la sangre y entonces hasta ahí ves cuantos huesos y entonces ~ // y después para una señal de tu cabeza ~y después tu cabeza no sirve también. [What happened is that ~ when it goes inside the body you can't take it out the // it's going to be all over the bone ~ it goes to all the blood and just then you can see how many bones so then // and then it stops the signal to your brain ~ and then your brain also stops working.] |
| 17 | Jorge: | Era muy tarde porque ~ el gobiernamiento no avisó a nadie ~. [It was too late because ~ the government didn't tell anyone ~] |
| 18 | Ethan: | El gobiernamento 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 and lead in // in the water but they didn't want to say anything because everyone was going to get crazy and hysterical.]

Lola wanted to know if the government at least tried to save the children after figuring out the water was polluted (unit 12) which several classmates at once rejected (unit 13), perhaps at this point convinced by the more critical arguments that had been made by classmates in support of the fact that the government tried to cover up the truth. Although Oliver thought the government may have tried to help (unit 15), Ethan was quick to point out that once lead gets in your body there is nothing that can be done to take it out because it gets everywhere and eventually harms brain function (unit 16). 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 (unit 17). Ethan's critical consciousness continued to guide the discussion as he reminded his class that the government wanted it kept a secret so that people would not "get crazy and hysterical" (unit 18). 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.

19 David: Can we let other people talk? Anyone who didn't say a single word please talk. ~

20 Yasmin: Um well ~ cual es ahora // este como // puede infectar a los demás porque// um ~ que no van a poder aprender tan fácilmente como otros y ~ como a los adultos no les afecta tanto ~ pero //um sí a las personas pero más a los niños porque apenas están aprendiendo? [Now // this like // it can infect everyone because // they are not going to be able to learn as easily as others ~ adults are not as affected but kids are learning.]

David became visibly agitated that more people had not been involved so far and perhaps he thought some of the more outspoken students were dominating the discussion (unit 19). Yasmin hesitated but did end up taking on David's challenge even though she did not seem comfortable talking at first. But as she spoke her shoulders relaxed and her ideas flowed more smoothly. Picking up on Lola's question about the children, Yasmin pointed out that lead poisoning harms children even more than adults because children with high levels of lead will not be able to learn as well as their peers (unit 20). This point that Yasmin made shifted the attention in the discussion to Ethan's invitation to his classmates to imagine the perspective of someone who actually has lead poisoning.

| | | |
|---|---|---|
| 21 | Ethan: | 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? |
| 22 | Dante: | Normal. |
| 23 | Students: | Normal? What? No! |
| 24 | Dante: | Because when it goes to your brain you feel normal but the other people on the outside are thinking you're not normal. |
| 25 | Student: | [camera was positioned to face the other way so I cannot tell who talked] Lead confuses your body. |
| 26 | Alan: | Your brain doesn't work really well. |
| 27 | David: | How do people even know that they are // they do know because the woman said their teeth are falling, their hair is falling. |
| 28 | Ms. Rosario: | I think what Dante // you're saying is as a child you don't know. |

Ethan, building off of Lola and Yasmin's expressions of empathetic care about the children, asked for everyone to shift their own perspective and try to imagine how a person with lead poisoning would feel (unit 21). Dante shared his idea that the person would feel "normal" even though this was not popular with his classmates, perhaps because they misunderstood what he was trying to say (unit 23) and he went on to explain that you wouldn't know because you would feel no different even though other people would know you were different (unit 24). Dante was taking on the perspective of a person with lead poisoning and imagining what it would feel like from their point of view, but his classmates interpreted his comments to mean that it would not affect the person's ability to think and learn. Ms. Rosario, seeing that Dante tried to shift his perspective to a child with lead poisoning, reiterated Dante's idea (unit 28). 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.

| | | |
|---|---|---|
| 29 | Alan: | Why don't // why didn't the government gave respect to the people? |
| 30 | David: | In the movie they said they switched it mainly to save money. |
| 31 | Alan: | Why does he care about more the money and he doesn't care // he only cares about himself and the money? |
| 32 | Oliver: | Maybe he does care about the people but he really wants the money. |
| 33 | Ethan: | The governor looks // Here's an example. The government is like a human and us, the people who live in Flint, are like ants. |
| 34 | Alan: | Then why did he do it on purpose? |
| 35 | Oliver: | No he did know // he didn't know the people were gonna get polluted by lead cuz he didn't know // cuz he didn't know a lot of lead was in the pipes, he only knew the water |
| 36 | Ethan: | Actually they did know. Because they had to put the chemical // the corrosion // they had to put it in the pipes cuz then // all the scientists know that the chemical that protects from lead // the lead is gonna go off. |
| 37 | Enzo: | They didn't want to lose the money or the kids too. |
| 38 | Ethan: | The school didn't tell the parents because they wanted the students to come so they could get money. |
| 39 | Oliver: | There's also a lot of high levels of copper. |
| 40 | Dante: | It also affects the earth because they are using a ton of water bottles. After the government found out they switched the water source back. Because people are dying for no reason. |
| 41 | Javier: | There is no reason why did the governor change the water. Because he knew that that water was dirty. He didn't use the corrosion control. You're supposed to use that for the drinking water in every state that's the law and he didn't use it. It's no reason why those people had to die. |

Alan' affective response had been building during this discussion and when he asked why the government did not show "respect to the people" (unit 29), the idea that the government was responsible for this atrocity sunk in more fully for him. He then reiterated his feelings, expressing his outrage that money could possibly be more important to the government than people's health (unit 31). When Oliver offered the possibility that they perhaps did not know how dangerous the lead was (unit 35), Ethan refuted this quickly, arguing that they should have known because they left out the corrosion control chemical that "all the scientists know" (unit 36) was needed. In other words, Ethan was not going to give 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 would simply not be an acceptable excuse. Dante pointed out that the extent of the damage went even further, in that it was not just the people's health that suffered, but also the environment because of the excessive amount of plastic water bottles that were needed to provide the Flint residents with clean water (unit 40). Finally, Javier offered impassioned thoughts, and expressed his outrage at the government's decision to break the law by not using the corrosion control, which caused people to die unnecessarily and unjustly (unit 41).

The emotionality increased over the course of the discussion, as the children shifted from giggling and lack of focus to calm, attentive bodies. They took on the perspectives of both the government and the people of Flint affected by lead, and it was clear that many children had visceral responses, noted in the shifts in their posture and attention from scattered and indirect to more focused and stilled, as well as their facial expressions which generally shifted downward, to the disregard for human life and evasions that the Flint government perpetuated. In this next illustration, Ms. Rosario's class took the ideas they discussed during this Socratic Seminar and turned them into embodied performances acted out from various perspectives.

### 2. **Illustration 14: Embodying the Government's Perspective**

In early February, Ms. Rosario invited each group of about 6-8 students to pick a perspective on the Flint Water Crisis and create an embodied performance, inhabiting different points of view and not necessarily ones with which they agreed. Group 1 chose the perspective from within the pipes, Group 2 chose the government's perspective, Group 3 chose to show what is happening inside the body with lead poisoning, and Group 4 chose the perspective of a family living in Flint. They started out by brainstorming on large pieces of poster paper, laying out different ideas for how they could enact the crisis from these unique perspectives.

Group 2 wanted to show the government came to the decision to switch the source of water from Lake Huron to the Flint River. 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 following discourse is not presented multimodally due to the limited image resolution of the recorded video of that lesson.

1 Braylon: Who's gonna be the pipes?
2 Javier: No, we're switching pipes so we are both open we are using both [sources of] water.
3 Leo: The pipes are the same except you just block the part where the Lake Huron water comes and then |
4 Oliver: You're the one that's gonna be this way [makes a t-shape with his arms in one direction, then switches to the other direction to show Javier what to do]
5 Leo: You're the one that closes it!
6 Oliver and Braylon: [gesture at Javier, showing him what to do by making t-shapes with their bodies]
7 Leo: Yeah, and you're the one that closes |
8 Oliver: You're gonna be // You're gonna be first like this [makes t-shape in one direction] |
9 Leo: And then when they switch you go this way and this man [referring to Javier] opens [Javier is trying it out with his body, making a t shape in one direction then turning it]. And then when they switch and this one opens I'll go voom!

There was tangible excitement and energy during the idea-generating process. They figured out how to show that the water sources switched. Javier would be in a t-shape with his body and turn the t-shape the other direction when the government decides to switch the source (unit 4), which they had already decided would be represented by Ethan pressing a button, made out of red construction paper, that they stuck on the wall. Leo, playing the part of the water, would then “go voom” on the floor sliding with his body past Javier (unit 9). The emotional intensity was building, as noted through the group’s pacing, light jumping and gesturing while trying to add their ideas, and the children became more invested in their roles, moving their whole bodies with Effort that would support their role, such as Leo sliding on the floor quickly to show water flowing. Isabel and Yasmin were also in this enactment, but it was not clear that anyone knew what their roles were going to be at that point, so they listened while the group rehearsed this new part, putting it together with what they had previously worked out.

| | | |
|---|---|---|
| 10 | Oliver: | We are going to get millions of dollars if we switch to the river! |
| 11 | Ethan: | Yeah, because Lake Huron is so expensive bro. It’s gonna cost millions of dollars and switching to the river is cheaper [smiling]. |
| 12 | Oliver: | Yes, let’s go! |
| 13 | … | |
| 14 | Ethan: | Not to worry [in a disingenuous tone, referring the previous comment in which a student was expressing concern], we’re going to put lots of corrosion control in it. |
| 15 | Oliver: | Yeah we’re gonna put lots of cleaning stuff in it [gestures pouring something out, continues with insincere tone of voice]. |
| 16 | Ethan: | Yeah a lot of Clorox in it. We’re gonna have millions [holds a stack of small rectangles of construction paper, representing bills, and beats it forcefully above his head]! |
| 17 | Oliver: | Money! Money! [Oliver hugs the student who was expressing concern, with his two hands gripping the student’s shoulders and then slapping the student on the back three times]. |

As the children got more invested in the perspectives they were trying on, the perspective of greedy officials who cared only about money (units 10, 11, and 17), it was clear they were portraying the joy they interpreted these officials to have as they were ensuring they were building up economical capital. Their emotional connection to the characters they were embodying was clear from the wide smiles on their faces and loud proclamations of making money while trying to assuage the moral dilemma that a student had raised (unit 13). Identity work was also going on here through positioning themselves as critical of the officials, but also brave to present this particularly vile perspective with as much commitment as they were showing in their roles, especially because of the inherent tension in representing a point of view one personally finds abhorrent. Their rambunctious movements (jumping, gesturing, hugging, slapping on the back) portrayed their thinking about the officials' preoccupation with their own wellbeing instead of the people's they were supposed to serve. In this way, the children helped the audience *feel* and, thus augment, the disregard for human life that a capitalistic system focusing on financial (and other) domination those in power have on society, and what Ethan had expressed in words in Illustration 1: "The government is like a human and us, the people who live in Flint, are like ants."

### 3. **Illustration 15: Yasmin's Science Identity**

Yasmin's knowledge and identity construction throughout the second half of the school year was particularly illustrative of the emotionality involved in justice-centered curriculum and the expansive identity roles it can make available. Yasmin's identity shifts started to happen when the class began learning about the human body and how lead affects its functioning. She was particularly interested in learning about how the brain is adversely affected by lead. Up until this point, which was in April and May, Yasmin had been more of a follower of others' ideas. She did get involved with the discussion in the Socratic Seminar, but took her time and only spoke a limited amount of times. She also appeared to enjoy working with her group on the Flint enactment although her role as the "cameraman" who recorded the government switching the water source was peripheral. But the next unit of study was the human body and unlike in previous years, when Ms. Rosario had groups research human body systems, this year she specifically tied the human body to lead and other contaminents, focusing the unit more on human health. 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.

Yasmin's science identity at school was supported by the fact that her mother was a scientist as well, at the time completing a degree in biology. Yasmin described her mother as a student and a scientist, and in this way, expressed solidarity with her. Ms. Rosario let Yasmin know that her mother's work was interesting and wanted her to come to the class to speak (which, unfortunately, did not end up materializing). During the BAS conversation in December, Yasmin shared the following about her mother:

> Well, like sometimes she works on zebrafish and she separates the males and the females and sometimes when they want to see the eggs of the babies some of them die every day. She's like a student and a scientist. I feel good because I can learn more about what she's studying and I can learn more about science and biology. Oh in science we acted like the water cycle and the groundwater and sometimes before she didn't know what groundwater was but then I showed her some videos that Ms. Rosario showed me. I think I told her Ms. Rosario was going to send her an email and wants to know what she is learning.

Yasmin talked about what her mother did with pride in her voice. By identifying her mother as a "student and a scientist" she was connecting her own identity with her mother's. By her description of her mother's lab work, it was clear that they talked about her work at home, just as Yasmin told her mother about her own science experiences at school. Yasmin was excited that her mother could teach her more about biology, but that she could also teach her mother, for example about groundwater, a concept she said her mother was not familiar with. In this way, Yasmin was positioning herself as an expert, further being like her mom. Her pride in her mother's work was reinforced by Ms. Rosario's recognition of her mother's knowledge as important and Ms. Rosario's desire to learn more about it.

Yasmin wrote on the BAS handout mid-year, "I feel like a scientist when I go to my mom's school because I help her." When asked if she could see herself doing science as a career some day Yasmin said, "Yes, because I can learn stuff and act it out. I would like to have the career of being a scientist because you can work on biology." When I asked her if scientists act out the way things work, she said that they did, "because like my mom is a scientist and she acts out the way things work." Acting had become, for Yasmin, integrated with the practices scientists use to help them create knowledge. She believed acting out science would help her in her future career, as she also thought that her mom was constructing science understandings in the same way.

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 mom, creating a poster to present to her class about how lead gets into the body and what it does to the brain. She clearly was committed to the ABC project (this will be explained further in Illustration 16) and, according to Ms. Rosario, took a leadership role in putting the presentation together. According to Ms. Rosario, when it came time to present their project at the local university, Yasmin's good friend, Camila, did not want to be part of the presentation because Camila did not think her English would be good enough. Yasmin convinced her friend to participate in Spanish, pushing back on Camila's assumption that the presentation had to be delivered only in English. Ms. Rosario discussed her pride in Yasmin for giving her friend the confidence to be part of the presentation and for developing her agentic identity 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.

### 4. **Illustration 16: Student Reflections**

Toward the end of the school year, Ms. Rosario's class experienced two unique off-campus experiences that tied into their justice-centered science curriculum. In May, the class traveled by bus to the large, public, research university where the larger partnership for this study has been coordinated, in order to see the full-length play about pollution that sixth graders from another school, wrote, designed, and were performing in the professional theater space available at that university campus. The play took place in the future, and was focused on the effects of air, water, and land pollution that humanity's current actions would have on the enviroment and on humans, exploring with a critical lens how people were affected disproportionately by pollution and environmental racism. As a compliment to this experience, in late May, the class participated in a city-wide call from yet another local university to present to a panel of lawyers and law students a problem that the class had identified and extensively researched. This was called the ABC Project and several schools from across the city took part in it. This illustration presents several students' responses to both of these opportunities and illuminates how their agentic science identities, both individually and collectively, were emerging while undergoing these experiences.

Ms. Rosario's class completed written responses to the play, reflecting on what they took away from the experience of watching this performance. Children expressed their affective 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. The emotionality that came through their written responses also reflected the greater sense of agency that was emerging in their class, collectively. David wrote:

> After seing [sic] the show now I'm thinking that there is a global problem. People are dying of pollution. Whatever pollutants like soil pullution, air pollution, water pollution and trash. Plastic is one of the main problems in the ocean if an animal eats plasic 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 [sic] was contaminated with lead. Lead sticks in your body forever. In air factories are polluting the air. They have carbon monoxide witch [sic] 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's reflections show his affective response to a dire message he came away with after watching the sixth graders' play–that pollution in all forms is causing death, both of people and of animals. He especially pointed out 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 agency as he pivoted from the problems to what could be done about them, both in terms of taking care of the earth and informing young children of how to minimize their exposure to lead. The class had recently decided that their final project of the school year would be to plan and enact an embodied performance about lead for the pre-k class and the kindergartners. They wanted to put on a play about lead, 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. Their decision not to do the play further underscores the collective responsibility to not just share what they learned but really spend time with the younger children talking about the ideas without causing them excessive worry. 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 towards change for people in their community. But deciding not to do it in a rushed way took to heart, in a very 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 deeply affective experiences where emotions emerge and get communicated in ways that words and images alone do not.

Alan's strong affective response to the sixth graders' play 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 benifit [sic] to the people. The people that pollut [sic] 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 [sic] a lot why not to pullut [sic] our Earth. After seeing the show I'm thinking how important our Earth and why not pollut [sic] because theres [sic] not going to be alot [sic] of animals and alot [sic] 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 suprized [sic] 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 clearly moved by the play, especially by the images that were projected on the screen that made him "surprised" and "sad." 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' need to understand helped him recognize the agentic science identities 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 his understanding of 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. Alan also believed that individuals should be responsible for contributing to reducing pollution on a smaller scale. He suggested that given the right tools, such as a watch, people could regulate their own behavior. In this way, he expressed that he was constructing agency at both individual and collective levels.

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 abut [sic] pollution." Thus, Dante connected his own positioning as a scientist to his political will and helping others understand the science that he was coming to know. His science identity was becoming intertwined with his political clarity (Freire, 1998) as he was living in an era when the official position of the US executive branch embraced ideologies, actions, and policies consistent with anti-science and anti-enviromental protections. At the end of the school year, Dante wrote on his BAS handout 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 "ABC Project because we explained about lead and it felt like a scientist. We explain about we need so much to stop lead like the Noah that the schools need to stop lead from increasing." Several other students mentioned the Noah water flushing system that Dante referenced.

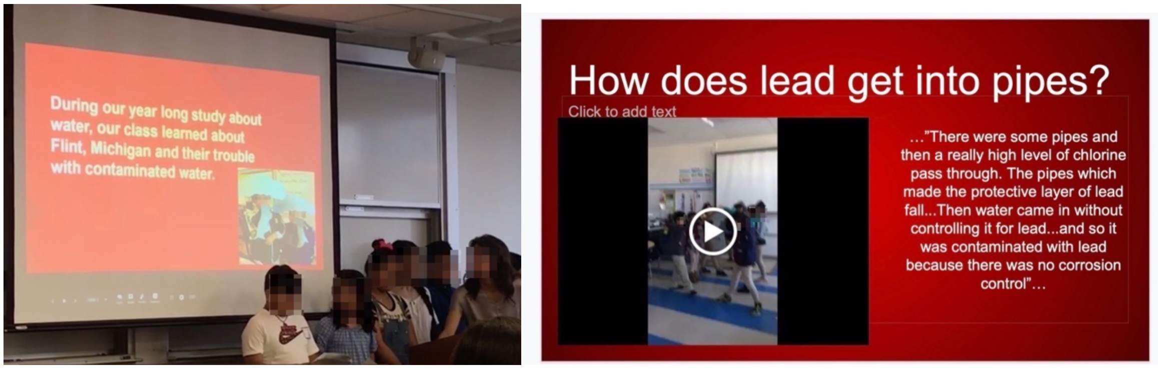
Ms. Rosario had found a story about a school building engineer, Michael Ramos, who had invented a system that he called the Noah to automate the process of flushing water through the pipes, allowing the orthophosphates added to the water to build up a barrier in the pipes. The class was impressed that this flushing system had resulted in low lead readings. A fellow city dweller who shared their ethnic identity as Latino had developed a solution for a problem that their community was facing too. In fact, Ms. Rosario had shared with her class a report by the school district that contained lead concentration measurements in water samples collected from multiple water fountains in district schools built before 1986, and 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). So for Ms. Rosario's students, the Flint crisis had connections with problems their own communties were facing. The students decided to each write letters to school allies, including the city mayor, the school superintendent, and the state governor, advocating for schools to install the Noah device. Ms. 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 agentic identities were developing around issues of water pollution, they thought it was amazing that a fellow Latino had found a solution and felt the responsibility to make sure that allies would hear about what he had invented from them, so they would consider putting his device in all of the schools in the district. After seeing the play that the $6^{th}$ graders performed, Leo wrote:

> I loved the show and how the students were so excited and dedicated to the show. I liked the part where it showed the ocean and how the animals in the ocean are affected by pollution. People should go see this show because it shows how pollution affects the world.

Leo was impressed by the performers' dedication and felt connected particularly with the images of the Great Pacific Garbage Patch and the animals surrounded by plastic that were projected on the back of the stage, and the performers' own embodiments of animals and the ocean during the play. The play reinforced his own beliefs that embodied performances were helpful to him and to his class in understanding science. After Ms. Rosario's class finished their ABC project, Leo took a question from a student from another school in the audience on how they came up with their idea to do a project on lead. Leo responded, "Actually in science, we started going with Ms. Rebecca // she came and told us about um 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." For Leo enactments of science ideas made it possible for the class to learn about lead pollution and its impact on the human body. Embodied performances made "science easier" and meaningful, bridging texts they were reading with their interpretations. In fact, collectively, this feeling was shared by the class as evidenced by the inclusion in their presentation of a video recording of an enactment they had done in their class (Figure 58).

**Figure 58**

*The Inclusion of Embodied Performances in the ABC Presentation*




*Note.* The image on the left shows a slide containing a photo of Dante and Javier in a science enactment. The image on the right is another slide containing a video of another embodied performance the students had enacted in their classroom, which they played for the lawyers and audience.

The importance of this presentation to Leo' science identity became clear on his BAS handout 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.

Leo was constructing an increasingly agentic science identity in which his own ideas were being considered important and valued. Over the year, he was consistently engaged in embodied performances, as shown in several illustrations, and, at the end of the year, he had confidence in his science learning, As he positioned himself as a confident 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.

Leo's pride in sharing useful information that could make a real difference in peoples' lives was echoed by Sandy as she reflected on the experience immediately after the ABC presentation. When the students were eating lunch after their presentation at the university, I asked her what was surprising about the project and she said, "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." Elaborating on how her class helped, she shared: "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." Sandy used "we" to place herself in collective struggle with the rest of her class. Her agentic science identity was intertwined with an activist collective identity.

Unlike Leo, Sandy, and Dante, who positioned themselves as scientists when they were presenting to others what they knew, Lola focused on the gravity of the science ideas her class was exploring, science ideas that were particularly important for young people's lives. She wrote on her BAS handout at the end of the year:

> 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 senti que era cientifica fue cuando estudiamos sobre el agua contaminada y el plomo en el cuerpo humano.
>
> *Eng. Trans.* I felt like a scientist at the time when I was learning about the human body and where the body and mind have lead 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 most like a scientist when she was learning about the effects of lead on the human body, especially how lead poisoning affects young children. Lola had been concerned about whether the Flint government was doing anything to help the children, as discussed in Illustration 13, and over time such empathy was intertwined with her developing science identity. 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 a sense of responsibility to use her knowledge to help others.

Perspective taking made room for intertwining affective, cognitive, and social dimensions of science learning, offering opportunities for both knowledge construction and identity construction that involved agency, care, and advocacy of others. By learning, in justice-centered ways, about Flint, the children became allies and activists in their own community. By researching lead data in their own school district, researching solutions, writing to officials such as the school superintendent and the mayor, they began to appreciate the complexity of these problems but also began to find hope in their collective work on their ABC project and planning to share their knowledge with their community. By participating in a letter writing campaign and doing a formal presentation about what they learned, Ms. Rosario's class learned to advocate by actually doing it, by writing letters to allies, researching and building prototypes that would cut down on pollution and health problems associated with it, and presenting their ideas with the

ABC project to lawyers involved in public policy, they embodied their agentic science selves individually and through collective action. The embodied performances they designed and enacted themselves, and those they watched sixth graders from another school perform, were front and center in both their knowledge and identity construction.

# VI. DISCUSSION

This study explored how embodied performances shaped construction and communication of science knowledge and identities among Latinx fifth graders. Embodied, multimodal, and aesthetic pedagogy contextualized the exploration of how children used their bodies as sites of knowledge construction and positioning in science as they engaged with increasingly justice-centered ideas. The findings point to the affordances that children collectively created and attributed to embodied performances as they made meaningful semiotic choices individually and collectively, and intertwined with affect, while constructing multiple representations for the whole class to then reflect upon in dialogic ways. The study also revealed challenges that together with affordances point to implications for practitioners and scholars who are interested in intersections of science, embodiment, and the performing arts, and are concerned with expanding multimodal approaches in science education.

## A. **Conclusions**

Embodied practices such as movement and drama are undertheorized as multimodal tools for teaching science and as a result, the literature provides few examples of performing arts and science pedagogies coming together in US classrooms. Consistent with the current framework for US science education (NRC, 2012) that calls for expanding active and engaging science experiences for children, such embodied pedagogies offer ways to accomplish this by allowing children to explore how the natural world works through "enacting conditions of possibilities, interruptions, interpretations, and play(ing) with variable relations" (Fels & Meyer, 1997). The present study provides evidence that efforts to bring embodied performances into the science classroom, such as those undertaken by Ms. Rosario, provided elementary school children, who have been historically minoritized in many different ways in US science education, a productive form of engagement with science and the world.

The children in the study transduced meanings across various modes and translated meanings within the same modes, extending each other's thinking and building ideas in collective ways. Embodied performances provided the spaces and places (Varelas, 2018) where children became collectively responsible to and for one another as performances took shape (Nelson, 2011) to both unboundedly explore ideas in science spaces and to feel a place of belonging in the science places they were creating in their groups. There was a genuine need for everyone in the group to act out roles within the performance, which meant that group members needed to help one another develop understandings. Therefore, they worked together to make sure the group's representation as a whole would make sense, as well as be interesting and engaging to the audience. When Manuel showed his group a way to act like the sun giving off its energy, even though this was not his role, or when Leía made sure Alan knew how to show the "dirty side" of the paper as he walked through the "pipe" to show that lead leached into the water, they were making sure that each group member's contribution would be a meaningful and important part of the overall representation. Children had to come up with something tangible, constrained by both time and materials, that both pushed further and expressed their understandings, which led to a genuine need for collectivity. This collectivity often manifested itself as children were transducing meanings among words, gestures, and movements, and were building ideas, asking each other to repeat their ideas, offering different suggestions, or doing the movements together while making adjustments.

Through these and other manifestations of collective meaning making, identities were also constructed as children positioned themselves as certain kinds of science people and certain kinds of collaborators. While children transduced meanings through dance moves, gestures, drawings, and dramatic roles, they also took up expanded available identities, including roles that may not be considered legitimate in a science class in which children's movements are constrained, and writing and speech often dominate communication. When children made successful "bids for recognition" (Carlone & Johnson, 2007) to their peers and teacher for having good ideas for enactments, or clever ways of showing science processes with their bodies, or being skilled at making props that evoked science entities, they felt confident doing science and began to see themselves and be seen as science people. These planning times were not without tensions and power dynamics. Participation was not even across the class with particular students taking on more opportunities to lead discussions and generate ideas verbally or with gestures and whole-body movements. Sometimes, only a few children involved themselves with the planning of enactments, discussing articles, or planning out posters. Other times, the whole group was activated in planning, interpreting, suggesting, and talking over each other to get their points across. Despite uneven participation at times in particular modes involved in these multimodal performances, the embodied performances were inclusive and inviting for many more children. The very fact that not all students' participation was noted during every activity underscores the importance of multimodal learning opportunities across the curriculum. Drawing, acting, building props, discussing, dancing, making costumes, doing experiments, and diagramming created different opportunities, for different children, at different times. Thus, taking the meaning making of children seriously in all modes can "problematize the privileged forms of science" (Philip & Azevedo, 2017, p. 528) and increase equity, defined here as expanding what counts as scientific practice, understandings, and identities.

Furthermore, if we do not take children's multimodal communication acts seriously, we are essentially ignoring the diverse array of meaning making in the name of the status quo of science teaching, which has historically been to uphold speech and written communication as the standard bearer, alienating many students and particularly emerging bilinguals like many of the children in this study. Although Bezemer and Kress (2015) associated multimodal engagement with a "generosity of recognition" (p. 5) of persons' meaning making, I consider such multimodal engagement as a right for all people, and a moral imperative for teaching so that all students' brilliance can be seen, accepted, and become foundational for their continuous learning. Particularly for emerging bilingual students, extended periods of collaboration, in which peers support each other using various modes of communication, have been an essential part of the guidelines put forth by the Committee of Fostering School Success for English Learners (National Academy of Sciences, Engineering, and Medicine, 2017). Embodied performances, as this study has shown, provide ample possibilities for such experiences.

Just as collective meaning making occurred in small groups while planning performances or interpreting results of an experiment, the whole class also made meanings dialogically during reflections on the embodied performances. It was during these whole-group reflections when the class grappled with each performance and pushed their understanding further. For example, Ms. Rosario and the students further clarified the states of matter enactment in Illustration 6. They guessed the intended semiotic choices of the performers and how they linked to various science concepts during their reflections on the aquifer enactments in Illustration 12. With the rest of the class and their teacher as the audience, performers adjusted their own thinking like when Eric suggested Braylon to position himself within the circle representing the cloud in Illustration 7.

Moreover, when learning languages, Gee (2008) argues, we learn words through experiencing them, in that "situated meanings are, crucially, *rooted in embodied experience*" (p. 164). Thus, embodied performances provided authentic and interactive opportunities to negotiate meaning and decipher new vocabulary, benefiting children's language development (Ntelioglou, 2011). Abril and Yasmin both mentioned how helpful reflecting on the embodied movements was to them in terms of learning science vocabulary such as "evaporation" or "goundwater." These words became endowed with meaning when enacted in embodied ways and then further solidified through reflecting on these words and their meanings further during dialogic reflections.

Furthermore, these periods of extended dialogue during and after embodied performances offered distinct affordances to performers and audience. Playing the roles of audience and performers engaged in dialogic reflections, students in Ms. Rosario's class were engaging in what Ford (2012) argues is essential to scientific practice, namely, being both "constructors and critics of knowledge claims" (Ford, 2012, p. 211). The performers benefited from hearing the audience interpretations and confusions, while the audience benefited from seeing the unique way of representing the ideas put forth by the performers. As asserted by Aubusson and Fogwell (2006), the most useful feature of science role-plays were not the role-plays themselves but the discussions that followed. In fact, different children in the audience could have different interpretations of the same performance, as we saw when Alan thought Javier's wavy movement represented water molecules, while Leía and Leo saw Javier's movement more as a body of water at the macro-level. Embodied performances offered opportunities for celebrating and building on the "multiplicity in human perception" (Holquist, 2002, p. 22).

In addition, just like in the planning process, during reflections after the performances, children voiced their observations and made unique connections that positioned and recognized them as certain kinds of people to their peers. During reflections, when children asked questions and made unique guesses and interpretations of others' performances or connected those performances to analogous ideas, they positioned themselves as thinking scientifically. "By expanding what tools are used, and what is valued in science classrooms, students are able to draw on a greater range of identities for their full participation" (Varelas et al., in press). When Javier shared that he realized from another group's performance that the water cycle never stops, or when Alan brought in ocean waves to discuss further the absorption of water into sand, or when Oliver and Leo brought up that the movement of the water through clay was too forceful, they showed confidence in their thinking, they recognized each other's contributions in the development of that thinking, they questioned each other's thinking in the quest for meaningful understanding–all important dimensions of multi-faceted science identities.

When children compared multiple embodied performances on the same topic, additional affordances emerged. No one group could capture everything important in their performance, and different groups found different aspects of the phenomenon worth including or highlighting. The multiplicity of models that the students created with their embodied performances revealed different aspects of the science ideas they were developing and captured different aspects or scales of the same phenomenon, going beyond each model's limitations and spurring further discussion and meaning making (Oh & Oh, 2011). In creating multiple embodied performances of the same science concept, the whole-body movement provided a representational tool that "productively constrain[ed] the focus of student meaning-making…bring[ing] classroom science closer to the knowledge-building practice of science itself" (Prain & Tytler, 2013, p. 68).

Multiple embodied performances of the same concept, whether it was the water cycle, permeability of earth materials, or aquifers, provided multiple ways of seeing these concepts and allowed comparisons across the different performances, as children noticed similarities and differences or discussed unique ideas that particular performances brought forth. What Ms. Rosario's class was engaged in, when looking for similarities and differences across multiple representations, was "relational generalization" of similar patterns that helped them understand the concept and develop "a more abstract schema for a category of situations" (Holyoak, 2012, p. 235), for example several groups representing condensation as a coming-together or bunching movement with their bodies helped the class overall develop an analogy for condensation that was not only scientifically sound but also felt through embodiment. When children were empowered to construct multiple embodied models of a concept, with few parameters other than to include movement and interaction, ingenious ways of bringing abstract scientific ideas came through pointing out unique aspects of each idea.

Along with the ingenious ways children thought about and communicated science ideas, this study also documented the range of emotions that were expressed in Ms. Rosario's science class while doing embodied performances. When the children, through artistic processes, took on perspectives and viewpoints of other people and entities and expressed these perspectives, they experienced and shared affect that science was evoking for them. Taking on and acting out these perspectives had ideational, social, and affective significance for children. When children empathized with the perspective of a person poisoned by lead or embodied the recklessness of the Flint government officials, or laughed and danced along with the performance of the water cycle because everyone knew the Fortnite dances, these opportunities offered them ways of expressing an array of emotional connections to the science they were learning and opportunities to see that science is intertwined with their own lives and the (in)justice in the world. 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 agentic science identities in various ways. 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. Mia used her own developing knowledge about, and recognition of, environmental issues related to water to teach her little sister that it was important not to waste water at home. Alan and David expressed their disbelief that the Flint officials would care more about money than about people's lives during Socratic Seminars, and Ethan and Oliver embodied the joy that money brings to some while others are suffering. In other words, these students' agentic science identities were able to flourish when emotionality and perspective taking influenced, and were influenced, by their developing science knowledge.

Emotionality is often lacking in science instruction, especially for younger students who are often deprived from digging into understanding, problematizing, and interrogating aspects of their and other peoples' lives in both physical and social worlds, and imagining different futures. Aesthetic experiences in the classroom could get children to think and react emotionally to a "multiplicity of new stimuli" (Greenwood, 2011, p. 51) without trying to take away the complexities, but rather explore and embody them. In fact, emotions and identities are related in complex ways (Maulucci, 2012). 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 with water distribution in the majority Black city in which they lived. Their study suggests that, although some are cautious about exposing elementary age children to complex socio-scientific and ecological problems because of the fearful emotions that could result, young children experience justice-centered curriculum in profound ways, with agency, not fear. As affect and emotions were deeply experienced in embodied ways, both individually and collectively (Lenters, 2018), in Ms. Rosario's class, the children's embodied performances became spaces and places to strengthen, for example, Lola's and Yasmin's identities as advocates for people's rights to healthy lives. Their science identities were expanding to include advocacy, care, and justice, intertwined with science understandings. 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 taking on the pessimistic view that there is nothing they can do about injustice, through agentic participation, they pursued the Freirean (1994) critical hope as they demanded unpolluted water:

> When it becomes a program, hopelessness paralyzes us, immobilizes us. We succumb to fatalism, and then it becomes impossible to muster the strength we absolutely need for a fierce struggle that will re-create the world…No, my hope is necessary, but it is not enough. Alone, it 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)

## B. **Methodological Affordances, Challenges, and Limitations**

The conclusions shared above were derived from a methodological approach that combined different analytical schemas: Halliday's metafunctions (applied not only to language but others modes too, including body movement) and the Laban/Bartenieff Movement System (LBMS). While Halliday's metafunctions brought into view scientific ideas and social interactions, the LBMS drew my attention toward the specifics of movement that constituted Halliday's "text" in this case. Body, Effort, Space, and Shape offered a way to see children's scientific knowledge and identities being constructed and communicated in a mode different from language. If we consider that movement is a communicative mode and that our embodied experience in the world is critical for developing communicative and thinking skills (Studd & Cox, 2019), then movement needs to be analyzed in terms of its own qualities, and in coordination with other modes, in order to develop deep understandings of the children's learning, thinking, and communicating. For example, when a child moves their arms and hands upward to represent evaporation, but also makes a spreading Shape with their arms while wiggling their fingers above their head and all around, with light but sustained Effort, the child is not only communicating that water vapor goes upward, but also that water vapor travels unboundedly in all directions.

Movement analysis using LBMS not only revealed meanings children were constructing relating to science knowledge, but also identity work that was unspoken. For instance, in Illustration 5, the four students enacting different parts of the water cycle increased their sustained Effort each time Ms. Rosario asked them to repeat their movements and make them more obvious to the audience. Whereas they started out unfocused and prone to giggling, they increasingly became more committed to their movements through calm and sustained Effort while also communicating the water cycle more clearly by holding the Shapes they were creating long enough to allow their classmates to understand what they were representing. Furthermore, in Illustration 13, during the Socratic Seminar, the bodies of the children could easily have been overlooked because students were seated while discussing complex ideas related to Flint. But considering their bodies through the analytical lens of LBMS allowed me to notice a shift in how they were holding their bodies as well as a shift in facial expressiveness that happened alongside the increasingly affective response children were having to the discussion of the injustice of the water crisis. Thus, the methodological approach used in this study offered important affordances that would not be possible if one or the other analytical lenses were used. Their combination proved to be a productive approach for this and future studies.

However, these analytical affordances should be considered in the context of data collection limitations despite steps taken to minimize as many of them as possible. Collecting video data to then analyze embodied ways of learning science presented unique challenges. First, when video recording movement, it is important to capture whole bodies in the frame, even when children are speaking more than moving. This allows analysis of movements of the hands and body that co-occurred with the speech. Although I had captured this to some extent, many more whole bodies would have been captured if this were a priority during recording.

Another challenge was that throughout the year, on the one hand, my very presence in Ms. Rosario's class may have been a distraction to students and the teacher in some ways, and, on the other hand, it may have also contributed to a higher degree of participation in embodied performances because the teacher did have some additional support in the classroom. Moreover, Ms. Rosario and I have worked together in a professional development context so we have spent time and devoted attention to science instruction in a way that many elementary school teachers have not had the opportunity to do so. It is hardly a typical case when the teacher has planned and continues to plan embodied science together along with other teachers and researchers.

Furthermore, an unavoidable limitation was my positionality as an outsider looking in in more ways than one–culturally, linguistically, and historically. Limited command of in-the-moment Spanish language also inhibited efforts to understand how emerging bilingual students were constructing their experiences.

There was also no way to capture students' experiences by only being with them in one part of their school day. Lives are multifaceted and many strands of one's life experiences are going on at the same time (Ingold, 2011). There is a limited understanding to be gained when we only see students' identity construction in one context of their lives (Olitsky, 2006). In addition, conversations between a teacher and a student or a researcher and a student about their ways of thinking about an idea or positioning themselves are always co-constructed between the two interlocutors (Kane, 2012). In this way, the potential of my conversations with students to communicate their own ways of engaging with an idea and considering their positionings are by default limited, as conversations reflect the joint construction of meanings.

Furthermore, there was a tension between the study's focus on science specifically and Ms. Rosario's responsibilities as an elementary school teacher. There were times when more pressing things had to take precedence over the study, for instance testing, fieldtrips, and making time to catch up on reading or math instruction. Having been a classroom teacher myself for 10 years helped alleviate this tension as Ms. Rosario knew my solidarity with her, as a fellow teacher, would lead me to understand intimately her needs and time constraints.

Inherent in this study were also some of the same limitations that Johnson (2012) pointed out about science identity research, namely, that most of the research that we have either focuses on in-the-moment performances of science identities, *or* the identity work of those who have already persisted in science education and careers. In essence, we actually do not know much about how these two types of studies can be connected to help us shape, systemically, science programs that build upon science identity work over time, resulting in science trajectories (Johnson, 2012). Identity work happens over time, and even a year-long study on identity construction cannot provide sufficient data to understand science trajectories and critical identity shifts over long periods of time. Moreover, this study has neither the longitudinal nor the large-scale nature that Lee (2012) noted as needed for identity-based studies to bring about changes to curricula. Nevertheless, the study offered in-depth and year-long evidence of the forms and functions that embodied performances in science classrooms could have in relation to both science content learning and identity construction of Latinx elementary school students while exploring socio-scientific topics, thus, arguing in favor of the presence and incorporation of such performances in science classrooms.

## C. Implications for Future Science Education Research

To build on the findings and conclusions of this study, future research should continue to interrogate how embodied ways of enacting science knowledge and identities can extend what counts as science, in other words, expand the "epistemic heterogeneity" (Varelas et al., in press) of science practices in classrooms.

Future studies could explore the relationships between gesturing and whole-body movement. How do children's gestures, while their whole bodies are constrained from moving around while seated at their desks or the rug, inform the whole-body movements they create once given those opportunities? Do the whole-body movements stem from or become rooted in the gestures? Building off of the research on metaphoric gestures proceeding abstract science language (Roth & Lawless, 2002), future research could explore how whole-body movements in similar and perhaps different ways than gestures, proceed abstract science concepts and processes as well. Is there some value in the more constricted movements of gesturing with only hands and arms being developed first before students are then asked to create whole body movements? How do children see the relationship between gesturing and whole-body movements? Future studies guided by such questions could explore what happens when children are made aware, metacognitively, of the gestures they are using to explain scientific phenomena and asked to explain how these gestures represent the ideas.

It would also be beneficial for future studies to explore how the teacher's dialogic structures during reflections of embodied performances get taken up when the teacher gives over the responsibilities of dialogic conversation to the students. Do children begin to internalize the dialogic structures over time and are they able to structure, eventually, their own reflections with more limited support from the teacher? Moreover, how are children, individually and collectively, negotiating decisions about whole-body movements when they are working in groups and is the collectivity of meaning making operating in sustained ways over time among groups of children?

Cataloguing kinds of questions that help children think across different embodied performances is also needed. What forms may scaffolding take to support students as they compare and contrast multiple representations linking embodied performances with each other and with other representations such as drawings, diagrams, or photographs? Future studies could also explore similarities and differences between the nature of scaffolding that is needed while embodied performances are composed by the performers themselves versus the scaffolding needed from the audience after the first iteration of an embodied performance.

Additionally, future research could explore how children's agentic science identities develop further and get nurtured when embodied performances are created into cases that can be shared outside of the classroom walls, with other classrooms, with parents, with the community, and in virtual spaces as well. In what ways do children continue to do impactful identity work in science when they work on social justice performance projects in their community?

Given that teachers' views of embodied performances in science classes is the first step towards further exploring students' performances, another direction for future research could be to explore teachers' perceptions of the value of using embodied performances in science. It would be crucial to understand the epistemic, affective, social understandings, and identity work that teachers experience when doing embodied performances of science both with other teachers and with their students. Additionally, understanding which types of embodied performance activities science teachers find most successful for meaning making, from narrated or scripted short plays to more improvised or movement-based enactments of science, is important.

Lastly, given the high level of engagement and content understandings when science is presented to the general public through the performing arts (Schwartz, 2014), the performing arts could infuse school science with much needed engagement, understandings, and emotionality, which is so necessary for engagement as well. Researchers and practitioners at the crossroads of science, performing arts, and justice-centered pedagogies need to probe more deeply into the particular affordances that embodied performances offer in the exploration of social justice issues and their intersections with science ideas. This work is particularly timely considering the ever-increasing need for public engagement with critical science. The arts can engage the human spirit deeply in science and through that engagement, inspire the work that needs to be done in order to care for humanity and our planet. Our future will be determined by how we nurture the spirit of scientific wonder and interconnectedness to the social world and to do so, young people need to develop expanded literacies, engagement, identities, and knowledges. Only then will they be able to meet matters of racial, socioeconomic, health, and environmental justice head on, with critical hope.

## D. **Implications for Science Education Practice**

While future research could further interrogate and illuminate several of the findings and conclusions of this study, the data from Ms. Rosario's class point to several recommendations for science education practice. Embodied performances have the potential to transform science classrooms into spaces and places of learning where the students' bodies are part of the journey as much as their minds. For that to happen, students need guidance in order to plan, perform, and reflect on embodied performances so that these embodiments become meaningful and impactful experiences for them. In Ms. Rosario's class, this need for scaffolding did not significantly lessen as the class practiced more. Thus, the pedagogical decisions that are needed in order to create space for embodied learning in science classrooms are considerable.

In Ms. Rosario's class, the most interesting and useful embodied performances were *dynamic*. Children using their bodies alone was not enough to gain from the full affordances of embodied performances. Stationary images created with bodies and props merely recreated other images, such as a diagram, without enabling the special affordances of *movement*. For example, the aquifer group that embodied a cross section of an aquifer with the various layers, used large sheets of butcher paper and costumes to represent similar ideas as the diagram without addition, expansion, or extension of ideas. Thus, it is important for teachers to be aware that without specific examples of different ways one could move to show aspects such as speed, shape, and level, students may create stationary images or models with very little movement, which does not accomplish much that is different from drawing a diagram or a picture. The unique affordances of movement need to be guided into the planning process. Starting out with whole-class enactments and the teacher using movement when describing science ideas, perhaps while reading science texts aloud, would be good ways to 'legitimize' and 'normalize' the use of movement in science, especially for reluctant students who may be shy or unsure if these ways of moving will be socially acceptable and who have experienced science education, and education in general, in ways that limit movement of their bodies that are usually controlled in school settings.

Another important course of action is to create the kinds of spaces and places for children to bring their ways of being into the classroom, and allowing them to improvise and have some amount of freedom in the way they plan their performances. For instance, allowing and encouraging children to get up on their feet and use some space in the classroom to try things out is necessary. If one was to walk into Ms. Rosario's classroom during planning time, they would hear laughter and various other sounds, see children on their feet, sometimes jumping, waving their hands when they had ideas, cutting out hats from construction paper and taping signs to their own and others' clothing, lying on the floor representing a lake or standing on chairs representing a rainstorm or the sun's energy. One would see Ms. Rosario traveling from group to group, checking in on how things were going and asking questions, perhaps making suggestions for how to finish up and move onto the performance segment of class time. In other words, classrooms need to be bustling with activity.

We know that dialogic teaching practices in science classrooms provide many opportunities to learners of science (Varelas & Pappas, 2013). For teachers with emergent bilinguals in their classrooms, dialogic practices could be particularly useful in both science knowledge and identity construction (Auerbach, 2000; Varelas et al., 2008, 2014). Ms. Rosario enacted dialogical practices. She was encouraging as many voices as possible to participate in both Spanish and English, often times allowing students to make their points and pose ideas without affirming or contradicting them but rather asking other students what they thought. She was usually reserving authoritative science positions until after students had a chance to talk through their ideas so they could link them with what has been scientifically accepted (Lehesvuori et al., 2011). She was holding her own ideas back, as well, while the audience talked about what they saw in a group's performance, even though she may have known what the group was intending to communicate by hearing about it during her check-ins with each group. She was holding back from agreeing and disagreeing with children's interpretations and asking them questions instead. In a way, the dialogic space for reflections on embodied performances was a reflection of Ms. Rosario's commitment to a type of classroom structure that "embrace[d] heterogeneous ways of being" which problematized "the normalized expectations of what science is and who can know" (Varelas et al., in press).

Ms. Rosario and I also noticed that there was a tendency to rush through the reflections in order for all of the groups to get to perform. But we learned that even if a few groups have to wait until the next day, that reflection time is so important that it should not be rushed. Another challenge for a teacher is to not become the director of each performance, jumping from group to group to ensure they have something to show. If some groups do not come up with anything in the time allotted, this could allow more time for reflection based on the performances of the groups that did come up with something.

In a way, this kind of embodied learning in classrooms is not only a resource for learning, but when teachers see the communication of students and themselves as embodied they can sense much more of what children are communicating in their classrooms and what children know. When ignoring bodies in the classrooms, and embodied ways of communicating, teachers and researchers miss out on what students are constructing both in terms of developing science knowledge but also developing identities. When we pay attention to ways in which children gesture or move their whole bodies while explaining a science concept, rather than only paying attention to their written and spoken words and even visual images they construct, we can get a fuller sense of how they are conceptualizing ideas and who in the class is taking up these ideas and how.

When Ms. Rosario asked her class questions such as, "what was similar about these two performances? What was different? How did this group show the aquifer and how does this compare to how this other group showed it," she was asking them to take into consideration multiple models into their thinking, which is what Prain and Waldrip (2006) found that students who developed a deeper conceptual understanding could do across multiple representations.

Putting embodied performances in practice in elementary science learning environments requires thoughtful approaches, scaffolding, and continuous reflection. However, the effort put in could be impactful for many more students than a diet alone of reading, experimentation, and writing in science. When children plan out and enact an embodied performance, an explosion of communication and knowledge construction could emerge, and teachers would stand to learn much about their students' understandings as they watch them engage in science while experiencing the joy that comes from connecting ideas in social, collective spaces in which their whole selves are invited to participate.

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# APPENDICES

## APPENDIX A

Name: _______________________________

Think of a time you thought of yourself and felt like a scientist. Make a drawing and describe the situation. Also explain why you were a scientist at that time.

**APPENDIX A (continued)**

Name: ________________________________

Think of **another** time you thought of yourself and felt like a scientist. Make a drawing and describe the situation. Also explain why you were a scientist at that time.

# APPENDIX B

## Symbols Used in Transcriptions

| | |
|---|---|
| // | Repetitions, false starts, abandoned language replaced by new language structures |
| ~ | Short pause |
| \| | Break of a speaker's turn due to the next speaker's turn |
| = = | A speaker's pause at the end of uncompleted utterance, seemingly to encourage another speaker to talk |
| # # | Overlapping language spoken by two or more speakers at a time |
| [ ] | Non-verbal information, (e.g., description of movement or who is being addressed) |
| Underline | Emphasis |

# APPENDIX C

## Movement Vocabulary

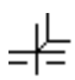
Created by Rachelle Tsachor (2019)[8]

### Themes of Duality, Categories and Components

Having words for movement can help everyone communicate.
These categories and components are from Laban Movement Analysis.

### Categories

LBMS identifies 4 categories of movement: **Body, Effort, Space, Shape**

| Category | | Observe | Can Express |
|---|---|---|---|
| **Body** |  | What is Moving + Body actions | Sensing |
| **Effort** |  | How it Moves | Feeling/Inner Drive |
| **Space** |  | Where it Moves | Thinking |
| **Shape** |  | Why is it Moving | Relationship/Intuition |

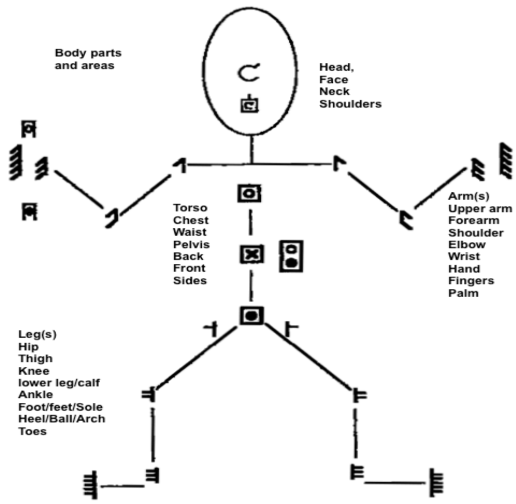
Each category names components, and sets of components

### Body

Body names body parts or areas, and body actions

[8] Reproduced here with permission.

## Body Part and Area Components




## Body Action Components

Posture, Gesture
Weight Shift, Change of Support (sit, stand, kneel etc)
Travel (locomote), Jump (skip, hop, leap)
Flex, Extend,
Scatter, Gather
Throw, Catch

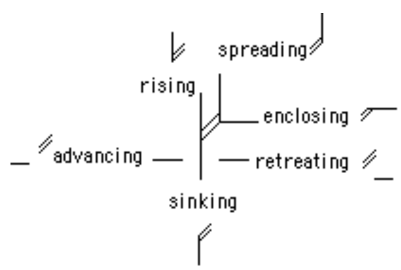
## Effort

Effort is the quality with which a movement is performed.
It expresses the inner drive to move.
Components: There are 4 factors with 2 elements each.

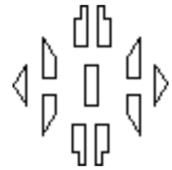
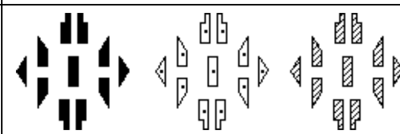
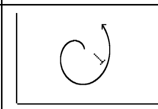
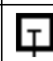
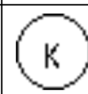
| Indulging | | Fighting |
|---|---|---|
| | *Space Effort--Attending (focus)* | |
| flexible/indirect-------------- | | -----------------direct |
| | *Weight Effort--Intending (pressure)* | |
| light-------------------- | | -------------------strong |
| | *Time Effort--Deciding (immediacy)* | |
| sustain-------------------- | | -------------------sudden |
| | *Flow Effort--Progressing (control)* | |
| free---------------------- | | ------------------bound |

## Shape

**Shape** refers to the way the body 'sculpts' itself in space.
It describes the changes in the relationship of the body parts to one another and to the surrounding environment when the body moves

| Modes of Shape Change | Relationship | Mode/Symbol |
|---|---|---|
| (Still) Shape Forms | Container of self Movement that doesn't adapt | Wall Ball Pin Screw |
| Shape Flow (open/close) | Self to self | Growing/condensing<br>Shrinking/expanding |
| Directional Movement<br>1-D=spoke<br>2-D=arc | Linking to environment | Spoking Arcing |
| Shaping (carving, molding) 3-D | Adapting/creating<br>Changing self in response to relationship |  |

**Space**

| Key concepts: | Description | Symbols |
|---|---|---|
| **Direction** | Judged from the mover:<br>(forward, side across, diagonal back)<br><br>Parts judged from point of attachment<br>(leg forward means forward from hip) |  |
| **Level** | Raising or lowering of the mover<br>(High is on balls of feet, low means bent legs)<br>Raising or lowering of a part.<br>(as judged from place of attachment) |  |
| **Path** | Mover's path across the floor.<br>(cross from downstage left to upstage right) |  |
| **Facing** | Orientation to the room/environment<br>(face upstage, then face stage right…) |  |
| **Kinesphere** | Personal Space (around each mover)<br>(the space you use without traveling) |  |
| **Reach Space** | Range in Kinesphere<br>(near, mid-range or far.) |  |
| **CPT pathways** | Movements occur in the Kinesphere along pathways: | |
| **Central** | towards or away from center |  |
| **Peripheral** | on the kinesphere's periphery |  |
| **Transverse** | inside the kinesphere |  |

**REBECCA KOTLER**
**Research Associate**

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|---|---|
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## EDUCATION

2020 PhD in Curriculum and Instruction: Mathematics and Science Education, Specialization: Science Education, University of Illinois Chicago, Chicago, Illinois

2006 M.Ed. in Elementary Education, DePaul University, Chicago, Illinois

2001 B.A. in Humanities, with Honors, University of Chicago, Chicago, Illinois

## AWARDS, HONORS, & GRANTS

2019-2022 PI: M. Varelas, Co-PIs: **R. Kotler**, N. Phillips, R. Tsachor, & R. Woodard, *Science Learning through Embodied Performances in Elementary and Middle School.* National Science Foundation (Award #: DRL-1908272). $752,724.

2019-2020 PI: M. Varelas, Co-PIs: **R. Kotler**, H. Natividad, N. Phillips, R. Tsachor, & R. Woodard, *Young People's Science Theater: CPS and UIC Students Creating Performances for Social Change*. University of Illinois Presidential Initiative to Celebrate the Impact of the Arts and the Humanities. $145,000.

2018 Chancellor's Award, University of Illinois at Chicago (UIC-wide award given to graduate students pursuing promising interdisciplinary research)

2015-2017 Dean's Fellowship Award, College of Education, University of Illinois at Chicago (award to one incoming PhD student per department)

2007 Summer Federal Grant for teachers (for mathematics curriculum mapping for 3rd and 4th grades)

2006 Summer Federal Grant for teachers (for designing a new social studies curriculum on Egypt for 3rd and 4th grades)

## PROFESSIONAL POSITIONS

2020-present Research Associate, Project STAGE (Science Theater for Advancing Generative Engagement), University of Illinois Chicago

2017-2020 Research Assistant, Project STAGE, University of Illinois at Chicago

Co-led meetings with participating teachers and researchers; wrote grants for external funding; visited classrooms to collect data on embodied science activities coordinated work on Young Peoples' Science Theater project

2015-2017 Dean's Fellow, College of Education, University of Illinois at Chicago

Developed Project STAGE with advisor (Dr. Maria Varelas); assisted IRB application and submission; completed an inquiry project on Science Theater with a 5th grade science teacher at a Chicago Public School; collected and analyzed data on elementary science teachers' science identity

2005-2015 Lead Classroom Teacher, Ancona School, Chicago, Illinois

Taught self-contained 3rd and 4th grades (2005-2014)

Developed and taught performing arts class for 7th and 8th grades (2014-2015)

Participated in various learning opportunities: Summer workshop on FOSS Science, week-long summer workshop in New York on Math in the City, Lucy Calkins Writing Workshop, week-long Reading Institute by the Reading and Writing Project in Teachers College, NY

2002-2004 Assistant Teacher, Francis Parker School, Chicago, Illinois

Assistant 3rd grade teacher for half day and assistant drama teacher for 1st-5th grades half day

2001-2002 Faculty Associate, Theater Arts, Northwestern University's National High School Institute, Illinois

Taught theater classes and assisted in directing final theater performance

**PUBLICATIONS**

**Books**

Glassco, S., **Kotler, R.**, Fosnot, C. (2017). *Tabletops, Floors, and Fields: Area, Perimeter, and Partitioning.* New London, CT: New Perspectives on Learning.

**PUBLICATIONS IN PROGRESS**

Varelas, M., Kotler, R., Natividad, H., Phillips, N., Tsachor, R., & Woodard, R. (in preparation). *"Science theater makes you good at science": Affordances of embodied performances in urban elementary science classrooms.*

**PRESENTATIONS**

Kotler, R., Varelas, M., Phillips, N., Woodard, R., & Tsachor, R. (2020, March). *Embodied performances, critical consciousness, and science identities: Latinx 5th graders' year-long study of water.* Paper presentation at the annual international conference of NARST: A Worldwide Organization for Improving Science Teaching and Learning Through Research, Portland, OR. (Conference Canceled)

Kotler, R., Varelas, M., Phillips, N., Tsachor, R., & Woodard, R. (2019, March). *Dramatizing science ideas: Multimodal science learning and generative engagement in urban elementary classrooms.* Paper presentation at the annual international conference of NARST: A Worldwide Organization for Improving Science Teaching and Learning Through Research, Baltimore, MD.

**SERVICE & LEADERSHIP**

| | |
|---|---|
| 2017-2019 | Developed drama and science integrated instruction with 4th grade teacher and his class, DeWitt Clinton Elementary School, Chicago, IL |
| 2016-2019 | Developed drama and science integrated instruction with 5th grade teacher and her class, Jorge Prieto Math and Science Academy, Chicago, IL |
| 2016-2019 | Developed drama and science integrated instruction with 2nd grade teachers and their classes, John Hay Elementary Community Academy, Chicago, IL |
| 2015 | Visiting Educator with the Embodied Design Research Group and Functions Research Group, Graduate School of Education, University of California Berkeley |
| 2015 | Reviewer of student assessment tools and teacher education materials at FOSS (Full Option Science System), Lawrence Hall of Science, Berkeley, CA |
| 2014-2015 | Developed curriculum for new performing arts class for 7th and 8th grade students, Ancona School, Chicago, IL |
| 2007-2010 | Led Parent Education, "Math Nights," Ancona School, Chicago, IL |
| 2006-2008 | Member of Chicago Lesson Study (CLS) Group and contributor to the first annual CLS conference, DePaul University |
| 2008 | Volunteer at APMSEC (Asia Pacific Math and Science Education Consortium), DePaul University |
| 2006-2010 | Led monthly Math Study Group for teachers, Ancona School, Chicago, IL |
| 2005-2014 | Coordinated annual integrated theater arts events, including Colonial Night, Poetry Café, Africa Night, and co-directed the annual Peace and Justice Play, Ancona School, Chicago, IL |