

'Be Creative and Have Fun': elementary-aged children's digital and embodied composing in science

Rebecca Woodard , Amanda R. Diaz, Nathan C. Phillips, Maria Varelas, Rachelle Tsachor, Rebecca Kotler, Ronan Rock and Miguel Melchor

Abstract

A team of literacy, science, and theatre educators have been working to engage children in an urban public school system in the United States through embodied performances, where students embody and dramatise science ideas. This study focuses on one fourth-grade classroom when instruction was done remotely due to Covid-19. Children in the class were asked to compose videos of themselves acting out and/or exploring science phenomena and concepts, and we analysed the affordances of these multimodal compositions. We situate the need for this study in claims from the Next Generation Science Standards that literacy skills are necessary to build and communicate science knowledge. In doing so, we center social semiotics perspectives that conceive of composition broadly as production-oriented processes drawing from various semiotic resources. The multimodal compositions in Mr. M's science class included both primarily embodied compositions and primarily digital compositions, and we elaborate on one focal example of each in the findings. Intertwined affordances of the focal children and their classmates' multimodal science compositions include opportunities to creatively engage with and negotiate science ideas, to draw from personal and social knowledge during meaning-making, and to intentionally make rhetorical choices.

Key words: composition, embodiment, multimodality, science, theatre, writing

The Next Generation Science Standards (NGSS) note that 'literacy skills are critical to building knowledge in science' (NGSS, 2013, Appendix M). As they learn science, children must engage in multiple literacy practices, including particular ways of reading (e.g.,

synthesising complex information and following detailed procedures) and writing (e.g., writing evidence-based arguments). In particular, the NGSS describe how 'writing and presenting information orally are key means for students to assert and defend claims in science, demonstrate what they know about a concept, and convey what they have experienced, imagined, thought, and learned' (NGSS, 2013, Appendix M). In practice, though, how do elementary teachers use writing to support science communication and learning? How do they foster expansive conceptualizations of writing, including through engagement with multimodal composing? And how might opportunities to compose matter in children's science learning?

These are some of the questions our team of literacy, science, and theatre educators have been asking through our work together on Project STAGE which has spent multiple years engaging elementary-aged students in a large urban public school system in the United States in *embodied performances*, where students use their bodies to dramatise science ideas (e.g., individuals acting out the states of matter; small groups working together to dramatise the water cycle; classes performing plays about climate change). This study focuses on the classroom of Mr. M (Melchor, co-author). When instruction in many places in the United States was taking place remotely due to the Covid-19 pandemic, Mr. M asked his students to embody and act out science concepts during online synchronous sessions and also invited them to compose videos where they dramatised and explored science concepts, often with directions to 'be creative and have fun'. In this study, we examine how two of the fourth-graders in Mr. M's class engaged in digital and embodied composing as they created these multimodal videos about science concepts and phenomena during online instruction. We asked: **What were the affordances of elementary-aged children's multimodal science composing?**

Funding information US National Science Foundation, Division of Research on Learning in Formal and Informal Settings, Grant/Award Number: DRL-1908272

A social semiotics perspective on composition

Social semiotics positions meaning-making as a dynamic process that involves 'actively 'remaking' ... information and messages (or complexes of 'signs')' (Jewitt et al., 2001, p. 6; see also Halliday and Hasan, 1985; Kress, 1997). A major focus in social semiotics has been on the multiplicity of semiotic resources people use to produce and interpret meaning (Van Leeuwen, 2005, p. xi), including written-linguistic, visual, audio, gestural, and spatial meaning systems (New London Group, 1996). In the field of literacy education, these ideas have led to a shift from thinking narrowly about writing (i.e., primarily focusing on linguistic/alphabetic modes) towards thinking more expansively about multimodal composing (i.e., embracing ensembles of modes, including linguistic/alphabetic, visual, aural, gestural, and/or spatial). From this perspective, composition can be conceptualised more broadly than is typical in schools as a 'production-oriented process that uses various semiotic resources to result in communicative artifacts' (Woodard, 2019, p. 2). This perspective acknowledges the 'changing nature of written texts' (Maun and Myhill, 2005, p. 7) in today's digital world, and encourages literacy teachers to shift pedagogical focus from conventional writing towards 'designing' texts with attention to both *what* is intended to be conveyed and *how* to best express it using multiple tools and/or modes (see Cope and Kalantzis, 2009). It orients teachers to focus on how the act of composing supports meaning-making and rhetorical choice-making, and on the affordances and constraints of different modes.

Literature review: children's multimodal composing in science

Literacy researchers have explored how multimodal composing in disciplines like science, social studies, and mathematics can cultivate children's meaning-making, content learning, and identity development (e.g., Dalton, 2014; Freeman et al., 2016; Pendleton, 2013). Aligned with the Project STAGE focus, we are interested, in particular, on children's digital and embodied composing in the discipline of science.

Children's digital science composing

While more research on digital science composing focuses on adolescents than children, recently, two teams of researchers have been exploring young people's

digital science writing. One team has been looking closely at how middle schoolers collaboratively write multimodal science texts (Jiang et al., 2020; Smith et al., 2019). They have examined how disciplinary role-taking (e.g., assigning youth to take on roles as a scientist, writer, or designer) during digital multimodal composing can support disciplinary identity development (Jiang et al., 2020). In one analysis, the researchers describe how youth selected relevant socioscientific issues and composed sci-fi narratives (Smith et al., 2019). Across their digital compositions, many students 'infused themselves and aspects of their lives into the narratives' (p. 53), for example by designing or describing characters to reflect themselves (e.g., their physical features, interests, or ways of speaking) or having characters embody specific roles to solve problems.

This research team has also explored how multimodal composition can afford positive science identity development by looking closely at children who took on the role of a scientist (Jiang et al., 2020). They found that such composing allowed students to develop their science identities, and that digital multimodal composing helped the students to see science as an active process (as opposed to a passive process of fact-learning) and a creative endeavour (see Masnick et al., 2010). It also helped some of them to 'realize science as an iterative process' (p. 3202), where they can develop their understanding of science phenomena. Finally, the researchers found that 'students viewed self-generated multimodal artifacts as not just representations of science phenomena, but also ways to communicate science ideas. In the process of creating artifacts, they paid close attention to the needs of audiences of their products' (p. 3207).

Another research team has explored younger children's writing in digital science notebooks (see Paek and Fulton, 2016; Paek and Fulton, 2021). For example, Paek and Fulton (2021) examined the ways second-, fourth-, and fifth-graders recorded information in their digital science notebooks, housed within a note-taking application on tablet computers. Their analysis found that the digital science notebooks allowed students to demonstrate their science knowledge in a variety of dynamic ways. In particular, students relied on the ability to take and embed photographs, which they used to support their explanations and to document their work. When documenting their own experiments, they often took photos from a variety of angles to provide clarity, and in some instances used digital tools to write over photos to provide detail. Students also used the audio feature to explain their thinking, as well as drawing features to sketch out ideas. These multimodal assemblages allowed children to both build and communicate their science knowledge.

Children's embodied science composing through dramatising

Another form of multimodal science composing that is relevant to this project is embodied composing, specifically through dramatisation. Both here, and in our previous work (see Varelas et al., 2010; Varelas et al., 2022; Woodard et al., 2023), we have explored embodied learning where children's bodies become sites of learning and meaning-making as they explore and improvise while learning science (Edmiston, 2003). In particular, we are interested in scholarship at the intersection of drama/theatre and literacy (e.g., Perry and Medina, 2011) situated in larger conversations about the embodied nature of literacy (e.g., Ehret and Hollett, 2014; Haas and Witte, 2001; see also Enriquez et al., 2015; Zapata et al., 2018). Dramatisation, including planning, coordinating, and performing role-playing and other kinds of dramatic enactments, is a form of embodied composing from a social semiotic perspective (Edmiston, 2013). As Perry and Medina (2011) suggest:

embodiment in performative pedagogical practices ... describes teaching and learning in acknowledgement of our bodies as whole experiential beings in motion ... The experiential body is both a representation of self (a 'text') as well as a mode of creation in process (a 'tool') ... Within performative pedagogy bodies can be acknowledged, made visible, and moved to the center of pedagogical experiences. (p. 63)

Like other forms of composing, performative dramatisation is production-oriented, uses various semiotic resources, and results in communicative artefacts (see Woodard, 2019).

McGregor (2014) documented how 17 teachers in the United Kingdom experimented with a theatre-based pedagogy in their science teaching, supporting children's social interaction, improvisation, and reflection. It was also motivating to learners. Åkerblom et al. (2019) explored how dramatising science made complex science domains, like chemistry, more accessible to preschool children. And Mutlu (2021) examined how fifth graders engaged in inquiry-driven dramatisation that supported both science learning and social objectives (e.g., empathy and social responsibility).

Varelas et al. (2010) explored children's dramatic enactments of science phenomena and concepts (e.g., creating a forest food-web drama; dramatically enacting the molecular behaviour in different states of matter). They showed 'children's multimodal ways of dramatising science ideas as a means of negotiating ambiguity of meaning and developing and communicating understanding' (p. 320). They argued that these

dramatic enactments encourage imagining and play that may not be possible with language alone (see Warren et al., 2001). They also suggest that dramatising creates hybrid spaces where students can bring their everyday funds of knowledge (González et al., 2005) into disciplinary learning contexts. They found that children collaboratively constructed meaning and that their 'conceptions of molecules or food webs were being constantly revised' (pp. 308–309).

Varelas et al. (2022) documented how children, working in groups ranging from four students to the whole class, engaged in collective meaning-making as they created small- and large-scale dramatic enactments (e.g., acting out parts of an ant for their classmates; creating and performing a science play for school and community members). As they enacted the same concept multiple times, students had opportunities to discuss and revise their ideas, and to grow their science understandings. The enactments also afforded opportunities to exhibit and reconfigure science identities.

In Woodard et al. (2023), we examined the playful embodied literacies of a fourth-grade student in her remote science class. This work documents the affective energies and playful learning demonstrated through a child's multimodal and embodied digital science compositions. In this piece, we argue that educators can and should 'give [children] time and space to engage with composing and tools to support embodied, digital, and tactile composing' (p. 174). Further, we note that such embodiments support students in their knowledge construction and development of their science identities.

Common themes across the literature on children's digital and embodied science composing include that it supports engagement with/interest in science and the cultivation of science identities, and it offers opportunities to revise and extend science understandings.

Method

In this qualitative study, we examined fourth-graders' multimodal composing through videos they created about science concepts and phenomena during online instruction.

Project STAGE

Project STAGE is an interdisciplinary collaboration between science, literacy, and theatre educators and researchers at a large public midwestern university in the United States and elementary and middle school science teachers. The aim of the project is to make

embodiment an integral part of learning in elementary and middle school science classrooms, particularly in schools that serve minoritized communities where the majority of the student population are students of colour and multilingual learners.

Mr. M’s class

During Mr. M’s fourth year in the partnership, due to the COVID-19 pandemic, his classes were held remotely for the majority of the school year. Mr. M identifies as Mexican-American and he was in his eighth year of teaching. One way Mr. M attempted to support embodied and multimodal learning during remote instruction was by using Flip (formerly Flipgrid), a video creation and sharing platform designed for schools. Within a private Flip room, which is only accessible to teachers and students, teachers post assignments and students create and share video responses. Flip camera features include filters, digital borders and stickers, and basic video editing (i.e., trimming, stitching). One way Mr. M used this platform was for formative assessments, where he assigned a topic and invited students to create their own videos exploring or describing a science idea, often with the directions to ‘be creative and have fun’.

The focal students in this study are Robyn and Audre (pseudonyms). Robyn is a Latina of Mexican heritage and a native of the city in which the project takes place. She is multilingual and speaks Spanish and English. Audre is a Black female. She and her family had migrated from Gabon to the United States a year earlier. She speaks French and English.

Data collection and analysis

The primary data source for this study is student-created videos from 12 different assignments that Mr. M created in Flip ($n = 189$). He created these assignments to supplement his fourth-grade science units about ecosystems, food chains and webs, and the solar system. To contextualise the analysis of these multimodal compositions, we also drew from videos of Mr. M’s online instruction.

We viewed each of the student-created videos from the whole data set ($n = 189$), using descriptive coding (Saldaña, 2013) to summarise each video. Next, we identified the primary mode used in each composition (see Table 1).

Since most of the multimodal compositions were embodied or/and digital, we focused on those and used inductive coding to identify the rhetorical moves (i.e., role playing/skits, talking directly to the camera and explaining ideas and images, ways of introducing topics, transitions, gestures and sound effects), the materials used (i.e., digital features, hand-drawn pictures, props and costumes), and who was in the video (i.e., friends and family members).

Multimodal composing in Mr. M’s science class

We first share two representative cases (Yin, 2009) that showcase the ways children in this class created multimodal science compositions: Robyn’s primarily embodied composition about food chains, and Audre’s primarily digital composition about Earth’s seasons.

Table 1: Coding of compositional modes across the data set.

Compositional modes	Description
Primarily embodied compositions ($n = 43$)	Students mostly relied on their bodies to convey information (i.e., skits, gestures and pointing)
Primarily digital compositions ($n = 46$)	Students primarily used digital tools to convey information (i.e., digital stickers and icons, informational slides, images and borders), including audio of their voices
Blended embodied-digital compositions ($n = 40$)	Students combined embodied and digital composing
Primarily print and drawing compositions ($n = 18$)	Students created drawings, concept maps, diagrams, and other visual representations to convey ideas, often holding their science notebooks up to the camera as they verbally described the images
Primarily oral compositions ($n = 35$)	Students orally shared their information without the creation of a compositional artefact
Other ($n = 7$)	Students shared other parts of their lives; bloopers; students shared how to use the digital tools of the platform. These submissions were not clearly linked to the assignment

The science-rich narrative displayed in Robyn's embodied composition was common among her peers, as was the manipulation of the digital stickers and tools seen in Audre's composition. We then present affordances of the children's multimodal compositions, which emerged from the analysis.

Robyn's primarily embodied composition

After learning about food chains, Mr. M posted an assignment for Flip that asked students to, 'Act out a food chain. Tell us what is the main source of energy. What are the producer, consumer, and decomposer? Be creative. Have fun. Can't wait to see it!' One student immediately submitted a video where they worked with their younger brother to act out a food chain. Mr. M showed this video to the class, and together they noticed how this child acted out characters, jumped across time, and showed energy transfer. Students commented that the video was both informative and entertaining, with Robyn noting that the video 'gave me ideas'. Later that same day, Robyn submitted her own food chain video.

In her food chain video, Robyn acted out, in sequence: a sun, a seed of grass growing, a rabbit eating the grass, a hawk stalking and eating the rabbit, the hawk dying, and worms discovering the carcass of the hawk and eagerly feeding on it (see Figure 1). Her video started with a digital border of neon flowers surrounding her, though she relied on her own body rather than these features to tell the science story.

The video begins with Robyn standing in a blue shirt. After introducing the topic of food chains, Robyn ducks out of view and emerges back on screen wearing a yellow dress over her blue top to indicate that she is now the sun. She spins around in her dress (that she 'loves' because 'it's so yellow') and explains that she, the sun, gives energy to plants that they need to grow and feed animals.

Next, Robyn turns off the light, and, in the darkness, the viewer hears 'Hey guys, just a little seed here. Just going to grow and grow and grow'. As the light comes on, viewers can see that Robyn has removed the yellow dress and is in her blue shirt. Her hands frame her face as she raises up while swaying side to side to mimic a growing plant. She explains she is now grass and will pass on energy to those who eat her.

She turns off the light again, and when it comes back on, she is a rabbit and dons a blue headband with bunny ears on it. She acts out eating grass before dancing around and singing 'Yeah, I got energy! I got energy, energy! I got energy!'

Next, Robyn removes her bunny ears, spreads her arms out like a bird, and announces that she is a hawk. She puts on a cat ear headband and lowers the register of her voice to explain that she is sneaking around to find bunnies to eat. Robyn then switches headgear and becomes the dancing bunny again, jumping and singing. She uses the headbands, her body language, and the tone of her voice to distinguish between the two.

Next, Robyn acts out a hawk approaching and eating the bunny. Robyn pantomimes scooping the bunny into her mouth 'to get energy'.

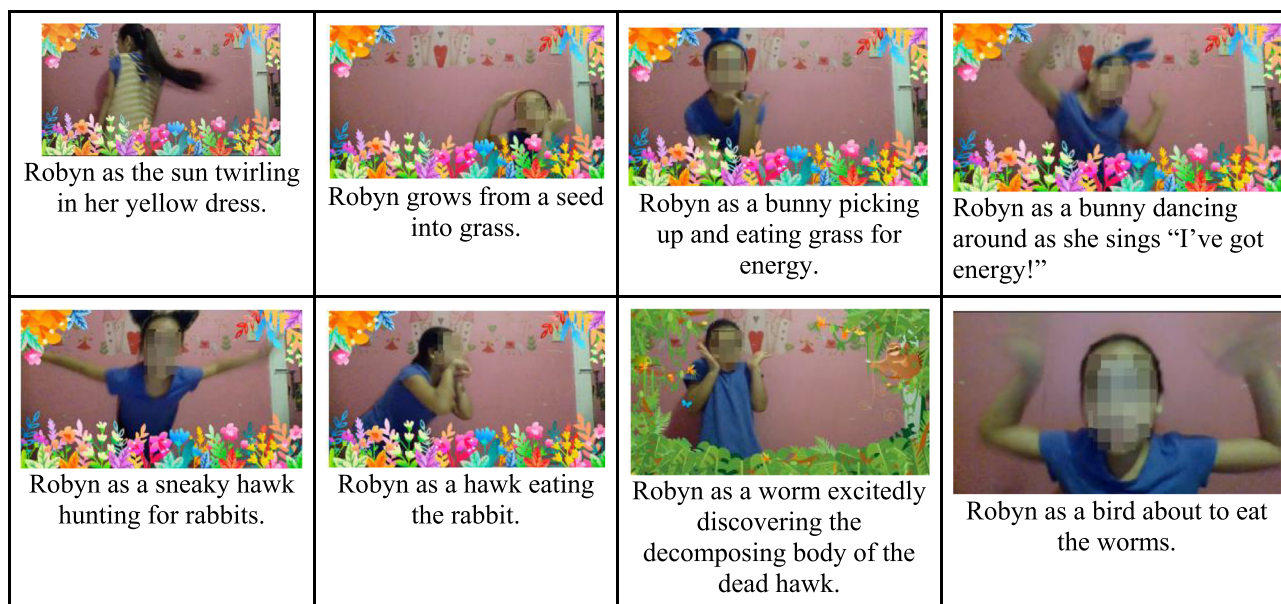


Figure 1: Still images from Robyn's primarily embodied food chain composition.

Then, Robyn leans forward and in an exaggerated and creaky voice, says '25 years later', while holding her back and hobbling around. She lowers her voice to become a hawk, and tells the viewers that she has eaten too many bunnies and has gotten old and thus has 'gotta die'. She then falls down out of sight.

Robyn emerges as a new character, a worm, and happily exclaims that she found a hawk and calls other worms over. They all start giddily eating the hawk. Robyn removes the filter and says 'Now we have to die. Bye-bye, birds are going to eat me'. Finally, she becomes a bird that eats worms, and the video ends.

Audre's primarily digital composition(s)

In exploring the solar system, Mr. M wanted his students to first understand how the Earth's rotation creates day and night. In class, Mr. M asked students to face their cameras and imagine their bodies are the Earth and their devices are the sun. As students mimicked the Earth's rotation by twirling around in front of their devices, they named the changing day/night on the front of their bodies.

Then the class moved on to the Earth's orbit/revolution around the sun. Mr. M used his left fist to represent the sun and his right hand held a pen with a pom-pom to represent the Earth. He aimed the pen with the pom-pom at his left fist and moved it around 'the sun' while simultaneously twirling the pen/pom-pom. Students also watched a digital video simulation of the Earth's double movements and how the Earth's tilted axis causes different seasons.

The day after watching this simulation, Audre tried to explain to Mr. M and her class why the Earth has seasons, but the concept was not yet clear to her. In her explanation, she revealed that she understood the Earth's orbit was related to it getting darker earlier in winter, but then she gave up and said 'I don't know how to explain this'. Mr. M asked Audre and her classmates probing questions to orient their understanding. Using his pom-pom pen again as a visual aid, Mr. M represented various orientations of the Earth and its tilt in relation to the sun (i.e., one where the axis was straight up and down, and another where it was tilted) and he and the students discussed how different parts of the Earth receive different amounts of direct sunlight as the earth orbits around the sun when the axis is tilted. Audre then offered that she was now ready to explain why the Earth has seasons, 'So, the Earth is tilted. When the northern hemisphere is towards the sun it's summer. When it's not tilted anymore it's going to be like winter or fall. And the time is changing, how you call it? Seasons. It's going to go slow. Spring, summer, fall, winter, and it goes around and

around'. As Audre was making sense of Mr. M's scaffolding, she was in the process of developing understandings. Although she was accepting the idea that because of the Earth's tilt the northern hemisphere would face the sun more directly during the summer, she was also considering that the tilt of the Earth changes and when 'it's not tilted anymore it's going to be like winter'. She was also communicating the idea that the orbit of the Earth around the sun was 'slow', possibly in relationship to the spinning of the Earth around itself that results in day and night.

Later that same day, Mr. M posted the following assignment in Flip: 'Explain why Earth has seasons. Use drama to model how seasons occur. Include words like tilt, northern hemisphere, southern hemisphere, and axis'.

Audre submitted two multimodal compositions related to the assignment the following week: one where the cursor was not visible because she was working from presenter view (i.e., **she** could see the cursor moving as the presenter, but it was not captured in the **audience's view** on the screen recording), and one where she fixed this issue so that viewers could also see her cursor move. Rather than acting out the science ideas in these videos, which was typical for her (see Woodard et al., 2023), both of these compositions were entirely digital. Audre explained that this was because her camera was broken.

We primarily focus here on the second video, which best captured her intentions as an author, while also noting two key moments from the first video. Of note to us from the first video was the way Audre made a joke to begin, laughingly saying 'Today we're going to be learning about locs ... just kidding, we're going to be learning about ... how we get seasons'. She then announced 'We're in space, dude!' as the background appeared. This playful introduction to her work helped us consider how she oriented her composition to her peers as an audience. The second notable instance from the first submission was when she thought aloud as she tried to manipulate her cursor. Viewers could hear her whisper to herself as she considered ways to represent the Earth's movement—a difficult task, given her available options in Flip. As she announced that she was going to share her screen so that viewers could see her presenter view and moving cursor, she jubilantly shouted, 'Boom shaka laka!' Though she had not yet solved the problem of letting the audience see her cursor, this excitement helped us to see the joy children can experience while solving complex problems with how to best semiotically represent their ideas through multimodal compositions.

We turn now to the second video where the audience *can* see Audre's moving cursor. It displayed the following slide as the main background (see Figure 2). The text across the top included 'each season show



Figure 2: This is the primary background in Audrey's composition.

different star and the earth tilit [sic] make season and day and night'. There were four digital icons of the earth, each labelled with a different season (spring, summer, fall, and winter), and Audre had drawn arrows to indicate how the earth makes a yearly orbit around the sun moving counterclockwise. Looking at this image immediately provoked a number of questions. We wondered: What did she mean by 'each season show different star'? Why did the Earth icons appear to be different sizes? We watched on in an attempt to learn more about her thinking, as we interpreted her labeling of the Earth's icons with different seasons as an indication of her thinking that a place on Earth has different seasons at different positions along the Earth's orbit around the sun.

Over the course of the next few minutes, Audre moves the cursor and different icons to represent the Earth's movements and narrates what she is doing (Figure 3). First, she drags the spring Earth icon around the sun as she describes how the Earth 'spins around the sun' which we took to describe the Earth's *yearly orbit* around the sun (see panel 1). Next, Audre moves the cursor in tight circles over the spring Earth icon, as she says that it 'goes around in a little circle', which we took to reference the Earth's *daily rotation* (see panel 2). Finally, Audre selects the winter Earth icon and tilts it, which tilts all of the other Earth icons, too (see panel 3). She explains that 'the Earth is tilted ... the Earth is not straight. Or we would never have seasons'. She then demonstrates how the Earth, with its now titled axis (and the same tilt for all the icons), 'spins' around the sun. She concluded by describing how the seasons change as the tilted Earth moves around the sun.

While we cannot know all of Audre's thinking from watching her present her digital composition (e.g., why each of the Earth icons is a different size), we do see Audre's deeper understanding about the Earth's tilt. Whereas orally, and before she created and

presented her digital composition, Audre talked about how the tilt of the Earth changes at different seasons, in her digital composition she correctly communicated that the tilt remained the same. Although Audre does not share *how* the tilt of the Earth leads to seasons, she correctly distinguishes in her digital actions between the two movements of the Earth, and correctly identifies the Earth's tilt.

Affordances of multimodal composing

The multimodal composition assignments in Mr. M's class supported Robyn and Audre, and the other children in their class, to build and communicate science knowledge using a wide range of semiotic resources. Three types of affordances emerged from the data analysis. First, the children's multimodal compositions provided them with a space to creatively engage with science ideas they were exploring. Second, their multimodal compositions supported their meaning-making that drew from personal and social knowledge. Third, via their multimodal compositions, children engaged in rhetorical choice-making.

Space to creatively engage with science ideas. By encouraging children to 'be creative and have fun' with their science compositions, and allowing them to make choices about the form of their video and submit multiple videos, along with discussing their videos in class, Mr. M created a space for playful exploration and meaning-making of science concepts. As in the work of Jiang et al. (2020) on multimodal science composing, the act of multimodally composing their science ideas was highly engaging for the children, and their engagement with science was active, not passive. For example, Robyn's engagement was evidenced when she noted that her classmate's video sparked ideas for her, and in the expansive ways she moved her body

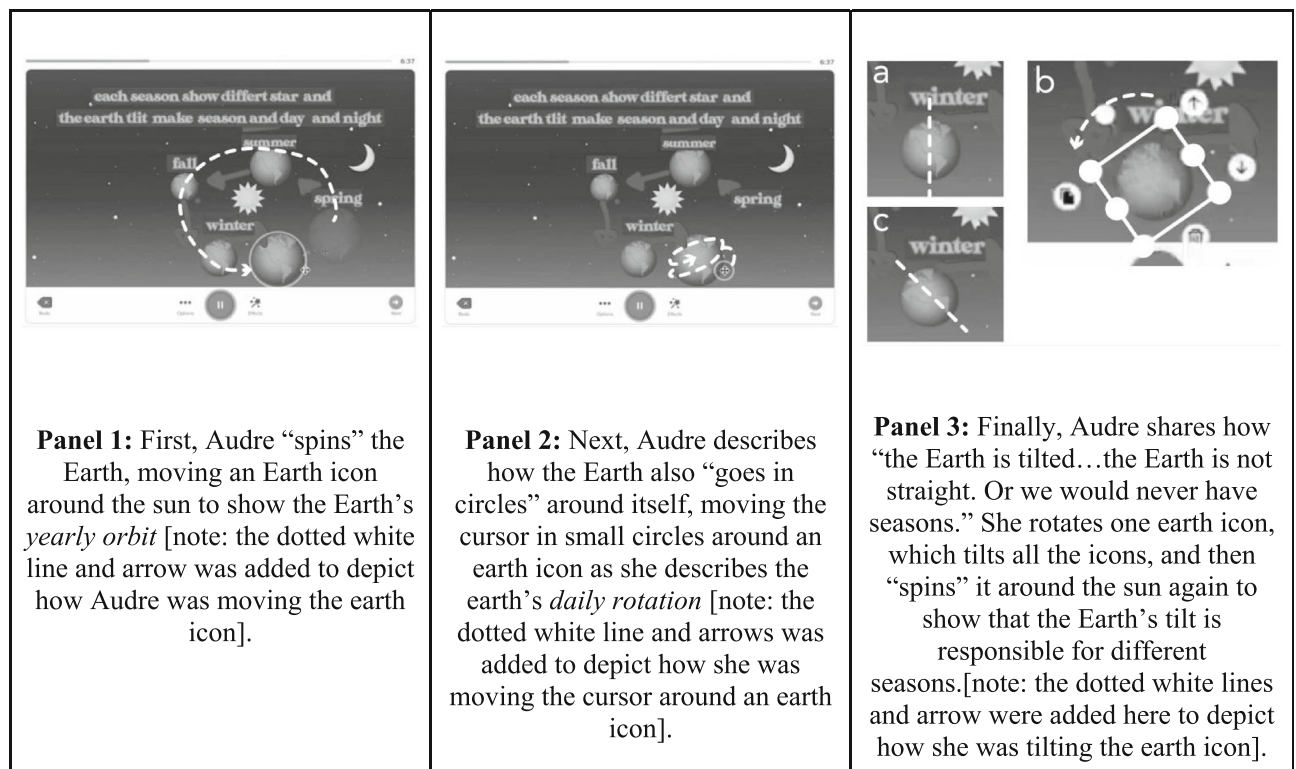


Figure 3: Screenshots from Audre’s second digital video about seasons, where the cursor is visible.

and changed her clothes, props, and voice to role-play new characters and story her science understandings in her own video. Audre’s video also revealed engagement. She put in extensive time and energy in order to create two different videos to best reflect her intentions, and she expressed joy when figuring out the representational challenge of helping viewers to see her cursor (excitedly yelling out ‘boom shaka laka!’).

A particular affordance of multimodal composing, especially in embodied form, was that it offered the ability to showcase movement and dynamicity related to scientific concepts and phenomena. Robyn’s embodied multimodal composition supported the representation of the dynamicity related to food chains and the way energy is transferred. In addition to characterising the organisms involved in this relationship, she often used her hands to indicate the transfer of energy (see panel 3, Figure 1). Further, her excited dancing as a bunny represents the vitality the transfer of energy provides to living beings (see panel 4, Figure 1). Robyn also conveyed the passage of time in her embodied performance. One way she did this was by manipulating her environment, such as turning the light off and on to represent the change from day to night. When she embodied growing grass and used a creaky voice to indicate that the hawk has grown old, she also represented the passage of time. In Audre’s case, representing dynamicity through digital composing was trickier, but not impossible. She brilliantly dragged an

Earth icon around the screen to represent the Earth’s yearly orbit/revolution around the sun, moved her cursor in tight circles around one Earth icon to demonstrate the Earth’s daily rotation around itself, and titled all the icons to show the Earth’s tilted axis. Traditional writing presents more constraints in representing movement and dynamicity.

Their multimodal compositions also allowed the focal children and their classmates to use their imaginations to work out processes of change that involve movement which are complex and challenging to both think about and communicate with only verbal language. Furthermore, they allowed students to represent concepts they may not yet have language for, as was the case for Audre’s representation of rotation and orbit. Though Audre did not use the words ‘orbit’ or ‘rotation’ in her video, the distinct movements she made with her digital tools conveyed the different ways the Earth moves and reveal how she was making sense of these movements (e.g., how they impact day/night on Earth, and its yearly seasons).

Perhaps most importantly, these multimodal compositions allow us to see children’s thinking and their developing science knowledge. They supported us to identify what questions we need to ask and what we can teach next. For example, Robyn’s embodied composition revealed that she has a rudimentary understanding of energy transfer through a food chain. It helped us to know that she may be ready to engage

with more specialised vocabulary (e.g., trophic levels, primary producers, decomposers) and complex ideas (e.g., the varying rate of energy flow at different trophic levels). Audre also demonstrates a rudimentary understanding of why seasons occur. Her composition helps us to know that we may need to ask questions about why she is representing the earth as different sizes in different seasons, and to push her towards thinking about and sharing *how exactly* the Earth's tilt makes the different hemispheres have different seasons.

Aligned with literature that both digital and embodied composing in science learning can support negotiation of meanings, and iteration and refinement of ideas (Jiang et al., 2020; Varelas et al., 2010; Varelas et al., 2022), the flexible nature of Mr. M's multimodal composing assignments supported both of the focal children and their classmates to grapple with their developing ideas as they represented (and re-presented) them. The students' multimodal science compositions also allowed us, as educators, to consider how they were experiencing and imagining science concepts and phenomena. Most importantly, multimodal composing afforded these children opportunities to be creative and engaged with science learning.

Meaning-making that draws from personal and social knowledge. Children's multimodal composing also allowed them to draw from various personal and social knowledge, and to 'infuse themselves and aspects of their lives' (Smith et al., 2019, p. 53) into their science compositions, which has implications for their positive science identity development.

The children drew from various personal and social knowledge as they wrote and constructed science ideas. For example, Robyn's scientific storytelling was shaped by her understanding of the social world. We see this in her video through the anthropomorphic features she gives to the sun and the organisms she portrays (e.g., the joyful sun, suspicious bunny, sneaky hawk, and eager worm), and how each transfer of energy was accompanied by joyful expressions from the receiving organism. Robyn's affect-filled embodiments of each character, and empathy for them, were situated in her understanding of human emotions, what we consider as an important contribution of dramatisation to science learning.

Though Audre's body was not visually present, many of her identities were also evident in her digital composition, including her racialized identity. For example, she started the first video by jokingly explaining to her audience of classmates, most of whom were non-Black students of colour, that her video would be about locs. And while her audience cannot see her, this is a hairstyle she often wears, so referencing it evokes her image and physical form.

And when she believed she had successfully shared the moving cursor on her screen with the audience, Audre joyfully shouted 'Boom shaka laka', which is commonly referenced in popular culture including music and films.

In other videos across the class, children's compositions were shaped by their desire to include their siblings or use multiple languages, and by the material resources available to them. The ways in which the children intentionally included their family members and home languages, imagined and empathised with the various organisms (Robyn), and drew from their racialized identities (Audre) speak to the potential for multimodal composing to support disciplinary identity development (see Smith et al., 2019) and science learning that is also oriented to social objectives, such as empathy and social responsibility (Mutlu, 2021). Again, it suggests that multimodal composing offers some distinct affordances as compared to traditional writing assignments.

Rhetorical choice-making. In Mr. M's class, students had access to watch each other's multimodal compositions and sometimes they watched them together in class. Across the dataset, it was clear that many students saw their classmates as a potential audience and the purpose of these digital compositions as more than demonstrating comprehension to their teacher. Many students sought to make their viewers laugh and delight, and/or invited them to think more. As was the case for Robyn after watching a classmate's video, students often drew inspiration from their peers' videos and through the sharing of ideas and resources. A potentially unique affordance of digital and embodied writing, then, was this more expansive orientation to science writing—why folks might do it, how it might function, and who it might impact. The multimodal compositions supported the students' development of not just science knowledge, but also rhetorical skills, and, in particular, provided them space to make rhetorical choices.

The act of representing ideas in a new mode (see Kress, 1997) required children to be intentional as they wrestled with how to most effectively represent their ideas. For example, Robyn had to make decisions about how to represent a variety of actors (e.g., the sun, growing grass, a bunny, etc.) in her embodied composition. She used a chronological sequence, colour (e.g., yellow for the sun), props (e.g., bunny ears), and narration to help her, as a single actor, represent a food chain. Robyn's video also offers an example of how some children in the class storied science as they made embodied compositions, creating rich stories using a variety of narrative techniques like personification, characterisation, transformation, and sequencing. As she assumed the roles of different characters (e.g.,

hawk, rabbit), she also engaged in literary practices of empathising and perspective-taking (see also Varelas et al., 2010; Varelas et al., 2022). Audre also had to make decisions about how to represent the different movements of the Earth in her digital composition using the available resources in Flip. She creatively manipulated the Flip tools, narrating how she used her cursor to move icons in different ways as she represented the Earth's yearly orbit, daily rotation, and axis tilt. Both children made intentional semiotic choices to best represent their developing science ideas using the available resources they had, whether these included their body, clothing, and props (as in Robyn's case) or icons, arrows, and the moving cursor (as in Audre's case).

The children in the class composed with varied purposes (e.g., to inform and entertain) and to particular audiences (e.g., their siblings, classmates, and teacher). Students were keenly aware that engaging their audience was an important part of their compositions, something that Mr. M also emphasised in class. For example, in submitting a second clarifying video, Audre also demonstrated her awareness of the audience and how her digital composition would be understood. This aligns with literature suggesting that students pay close attention to the needs of the audience when they create and share multimodal science compositions (Jiang et al., 2020).

Choices about modes of expression and rhetorical structures were important for the children and gave them more opportunities to productively wrestle with science ideas and to express them. Further work is needed on how this flexibility of choosing compositional modes can support children to author science identities (see Jiang et al., 2020).

Conclusions & implications

What if elementary teachers offer children opportunities to 'be creative and have fun' as they play, explore, and iterate their science ideas through many kinds of composition? What if we invite students to draw from a variety of materials, resources, and relationships as important sources of knowledge and support in science learning? What if we create audiences beyond the teacher for multimodal compositions so that children can engage in meaningful rhetorical choice-making, and position multimodal compositions not as a space to evaluate finalised knowledge but as a space to see children's developing thinking and generate questions and next steps for our teaching? Elementary teachers can use 'writing and presenting information orally ... [as] key means for students to assert and defend claims in science, [to] demonstrate what they know about a concept, and [to] convey what

they have experienced, imagined, thought, and learned' (NGSS, 2013, Appendix M). This should include attention to the affordances of different kinds of multimodal composing spanning modes, including primarily digital and primarily embodied. Engaging students in multimodal writing for varied audiences and purposes helps them consider how to explore/represent ideas about science (and other disciplines, too) in ways that feel compelling and joyful, and that offers them opportunities to use their many available resources—including their bodies, objects/materials, digital tools and platforms, and multiple languages. Ultimately, fostering multimodal composing may support teachers to see children in more expansive ways, too—as rhetorically-savvy writers/composers, as relational beings, as playful and creative entertainers, and as knowers and doers of science.

References

- ÅKERBLOM, A., SOUČKOVÁ, D. and PRAMLING, N. (2019) Pre-school children's conceptions of water, molecule, and chemistry before and after participating in a playfully dramatized early childhood education activity. *Cultural Studies of Science Education*, 14.4, pp. 879–895.
- COPE, W. and KALANTZIS, M. (2009) 'Multiliteracies': new literacies, new learning. *Pedagogies*, 4.3, pp. 164–195.
- DALTON, B. (2014) Level up with multimodal composition in social studies. *The Reading Teacher*, 68.4, pp. 296–302.
- EDMISTON, B. (2003) What's my position? Role, frame and positioning when using process drama. *Research in Drama Education*, 8.2, pp. 221–230.
- EDMISTON, B. (2013) *Transforming Teaching and Learning With Active and Dramatic Approaches: Engaging Students Across the Curriculum*. Routledge.
- EHRET, C. and HOLLETT, T. (2014) Embodied composition in real virtualities: adolescents' literacy practices and felt experiences moving with digital, mobile devices in school. *Research in the Teaching of English*, 48, pp. 428–452.
- ENRIQUEZ, G., JOHNSON, E., KONTOVOURKI, S. and MALLOZZI, C. A. (Eds.) (2015) *Literacies, Learning, and the Body: Putting Theory and Research Into Pedagogical Practice*. Routledge.
- FREEMAN, B., HIGGINS, K. N. and HORNEY, M. (2016) How students communicate mathematical ideas: an examination of multimodal writing using digital technologies. *Contemporary Educational Technology*, 7.4, pp. 281–313.
- GONZÁLEZ, N., MOLL, L. C. and AMANTI, C. (Eds.) (2005) *Funds of Knowledge: Theorizing Practices in Households, Communities, and Classrooms*. Lawrence Erlbaum Associates Publishers.
- HAAS, C. and WITTE, S. P. (2001) Writing as an embodied practice: the case of engineering standards. *Journal of Business and Technical Communication*, 15.4, pp. 413–457.
- HALLIDAY, M. A. K. and HASAN, R. (1985) *Language, Context and Text: Aspects of Language in a Social-Semiotic Perspective*. Geelong: Deakin University Press.
- JEWITT, C., KRESS, G., OGBORN, J. and TSATSARELIS, C. (2001) Exploring learning through visual, actional and linguistic communication: the multimodal environment of a science classroom. *Educational Review*, 53.

- student role-taking as scientist in a media-rich learning environment. *Educational Technology Research and Development*, 68, pp. 3187–3212.
- KRESS, G. (1997) *Before Writing: Rethinking the Paths to Literacy*. London: Routledge.
- MASNICK, A. M., VALENTI, S. S., COX, B. D. and OSMAN, C. J. (2010) A multidimensional scaling analysis of students' attitudes about science careers. *International Journal of Science Education*, 32.5, pp. 653–667.
- MAUN, I. and MYHILL, D. (2005) Text as design, writers as designers. *English in Education*, 39.2, pp. 3–22.
- MCGREGOR, M. (2014) Chronicling innovative learning in primary classrooms: conceptualizing a theatrical pedagogy to successfully engage young children learning science. *Pedagogies: An International Journal*, 9.3, pp. 216–232. <https://doi.org/10.1080/1554480X.2014.899544>.
- MUTLU, A. (2021) An activity based on an inquiry-driven creative drama: 'stray animals need some shade'. *Science Activities*, 58.1, pp. 1–12.
- New London Group (1996) A pedagogy of multiliteracies: designing social features. *Harvard Educational Review*, 66.1, pp. 60–93.
- Next Generation Science Standards (2013, May). Appendix M: Connections to the Common Core State Standards for literacy in science and technical subjects. Retrieved from: https://www.nextgenscience.org/sites/default/files/Appendix%20M%20Connections%20to%20the%20CCSS%20for%20Literacy_061213.pdf
- PAEK, S. and FULTON, L. (2021) Digital science notebooks: a tool for supporting scientific literacy at the elementary level. *TechTrends: Linking Research & Practice to Improve Learning*, 65.3, pp. 359–370 <https://doi-org.proxy.cc.uic.edu/10.1007/s11528-020-00579-0>.
- PAEK, S. and FULTON, L. A. (2016) Elementary students using a tablet-based note-taking application in the science classroom. *Journal of Digital Learning in Teacher Education*, 32.4, pp. 140–149.
- PENDLETON, M. (2013) Through the lens: multimodal science, math, and literacy practices in an elementary classroom. *Meridian*, 16.1, pp. 1–12.
- PERRY, M. and MEDINA, C. (2011) Embodiment and performance in pedagogy research: investigating the possibility of the body in curriculum experience. *Journal of Curriculum Theorizing*, 27.3, pp. 62–75.
- SALDAÑA, J. (2013) *The Coding Manual for Qualitative Researchers*, 2nd edn. Sage.
- SMITH, B. E., SHEN, J. and JIANG, S. (2019) The science of storytelling: middle schoolers engaging with socioscientific issues through multimodal science fictions. *Voices from the Middle*, 26.4, pp. 50–55.
- VAN LEEUWEN, T. (2005) *Introducing Social Semiotics*. New York, NY: Routledge.
- VARELAS, M., KOTLER, R., NATIVIDAD, H., PHILLIPS, N., TSACHOR, R., WOODARD, R., GUTIERREZ, M., MELCHOR, M. and ROSARIO, M. (2022) 'Science theater makes you good at science': affordances of embodied performances in urban elementary science classrooms. *Journal of Research in Science Teaching*, 59, pp. 493–528. <https://doi.org/10.1002/tea.21735>.
- VARELAS, M., PAPPAS, C. C., TUCKER-RAYMOND, E., KANE, J., HANKES, J., ORTIZ, I. and KEBLAWE-SHAMAH, K. (2010) Drama activities as ideational resources for primary-grade children in urban science classrooms. *Journal of Research in Science Teaching*, 47.3, pp. 302–324. <https://doi.org/10.1002/tea.20336>.
- WARREN, B., BALLENGER, C., OGONOWSKI, M., ROSEBERY, A. S. and HUDICOURT-BARNES, J. (2001) Rethinking diversity in learning science: the logic of everyday sense-making. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, 38.5, pp. 529–552.
- WOODARD, R. (2019) Teacher-writer-crafter-maker: an exploration of how making mattered for one writing teacher. *Literacy*, 53.4, pp. 236–244. <https://doi.org/10.1111/lit.12179>.
- WOODARD, R., DIAZ, A. R., PHILLIPS, N. C., VARELAS, M., KOTLER, R. T., TSACHOR, R., ROCK, R. M. and MELCHOR, M. A. (2023) 'I Am. a Star.': exploring moments of muchness in children's digital compositional play and embodied science learning. *English Teaching: Practice and Critique*, 22.2, pp. 163–176. <https://doi.org/10.1108/ETPC-08-2022-0101>.
- YIN, R. K. (2009) *Case Study Research: Design and Methods*, 4th edn. Thousand Oaks, CA: SAGE Publications.
- ZAPATA, A., KUBY, C. R. and THIEL, J. J. (2018) Encounters with writing: becoming-with posthumanist ethics. *Journal of Literacy Research*