Families' Imaginations in a Meteorology Workshop: Imagining Weather Through Prototyping a Weather Station

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Abstract: The paper presents a qualitative case study of families' imagination practices around weather in two informal learning settings. The study investigates families' imagined weather phenomena and meteorological practices as they created weather stations using the prototyping tool littleBits. The work is grounded in cultural-historical theory related to artifacts, imagination, and science representations. Participants include 7 families from two weather workshops, and data comprise families' video and audio recordings. The findings show that prototyping artifacts — the technological tools — materially and culturally mediated how families imagined and represented science phenomena and practices. The study contributes to understanding the role of imagination in children and families' science learning and science representations.

Introduction

Imagination has been recognized as a valuable way to engage children in learning science concepts (Fleer, 2015) or designing technologies (Druin, 2010). Existing literature has explored how young children use imagination in play and storytelling to learn science (Andrée & Lager-Nyqvist, 2013; Hadzigeorgiou & Stefanich, 2000). Other research also found that imagination contributes to children learning science phenomena or concepts that are abstract. For instance, it is suggested that children's imagination could help them learn mathematical concepts such as abstraction and generalization (Presmeg, 1992). Stratford and Low (2015) showed that children used imagination to learn about meteorological variables that are hard to observe with the human eye like air pressure and wind. However, the role of imagination has not yet been fully studied in all science disciplines and contexts like family science learning in informal settings. As such, this study, as part of a larger design-based research study engaging families in science practices with STEM professionals, examines the role of imagination in families' science learning while they utilized a prototyping tool called littleBits to create weather stations in a meteorology workshop. The research question addressed is: *How did families imagine weather-related phenomena and tools through designing weather stations in a weather workshop?*

Theoretical framework

This work adopts a cultural-historical view on learning where human activity is mediated by artifacts in specific interactional contexts (Cole, 2017). Artifacts are material and conceptual in nature in that their meanings and purposes are shaped by their previous participation in human activity and the ways in which they are used in current interaction (Ilyenkov, 1977). Artifacts, then, physically and culturally mediate human activity, depending on how artifacts are put in use in a context by learners. With the perspective recognizing both the material and cultural characteristics of artifacts, the study investigates the interactions among artifacts, people, action, and the environment in informal meteorology workshops.

The work also builds upon Vygotsky's (2004) theory on imagination. Vygotsky sees imagination as a fundamental element for a person's cultural life, which sets the foundation for creative and scientific thinking. According to Vygotsky, people imagine what they are not able to see and think about what they have yet experienced. Imagination enables one to extend his or her spatial and temporal boundaries of experience based on prior and in-the-moment social encounters (Zittoun & Gillespie, 2016). Applying such conceptualization of imagination to children's science learning, Hilppö, Rajala, Zittoun, Kumpulainen, and Lipponen (2017) highlight the *expansive* (i.e., spatial and temporal dimensions) and *plausible* (i.e., exploring what a science phenomenon *is* and what it *could be*) dynamics of imagination in science education. Imagination, grounded in the sociocultural perspective, is not solely an individual activity but a shared, social endeavor (Fleer, 2015; Zittoun & Gillespie, 2016). Hilppö et al. (2017), for instance, studied the dynamics of imagination in students' joint meaning making processes of learning science. Prior work (Zimmerman, McClain, & Crowl, 2013) also found that when using a magnifying lens in a nature center, families often engaged in imaginative play and role-play as part of their process of learning to use the tool within their social groups. Taking children's imagination into account also foregrounds the embodied and emotional nature of science learning (Fleer, 2013). In the field of meteorology, how children perceive weather partly relies on imagination as weather is an experience of *feeling* (Stratford & Low, 2015).

Instead of touching and building perception *of* weather, children experience and perceive *in* the weather world (Ingold, 2005). Expanding on the experiential aspect of science imagination, we also examine the role of narrative in families' science learning. Narrative—story that relates to or goes beyond one's personal experience—has been used to communicate science to diverse audiences in a meaningful way (ElShafie, 2018; Hadzigeorgiou & Stefanich, 2000). Imagination ties with narrative in the sense that imagination couples with people's lived experiences as learners "make references to events and objects within the scope of their life worlds" (Hilppö et al., 2017, p. 25). That is, imaginative practices around science build upon learners' everyday lives and knowledge.

To investigate families' imaginative interactions while inventing weather stations using technological tools, the study also examines the science representations that families created. What children choose to include in their science representations influences how they learn new concepts (Greeno, 1987). Children's choices for selecting, creating, understanding, and using science representations are mediated by multiple factors such as resources and ideas that are available in an activity (diSessa, 2004), individual preferences, children's understanding of the science content (Danish & Enyedy, 2006), and the cultural context in which the practice of presentation is performed (Hall, 1996). The act of creating representations is also embodied and multimodal (Goodwin, 1994). As such, it is important to understand representation as a form of practice that involves children negotiating, organizing, and prioritizing mediators that comes into the representational act (Danish & Enyedy, 2006). Children's prior knowledge is also seen as a resource that contributes to the creation and use of representations. Azevedo (2000) argues that children's prior knowledge related to a discipline or a concept can be used as *constructive resources* and be implicated in the process of creating relevant representations. Adopting such conceptualizations of science representations, the study pays close attention to the resources available to and taken up by families during the weather station creation activity. Connecting to the theory of imagination, the science representations co-constructed by families were understood by taking families' science imaginations into account.

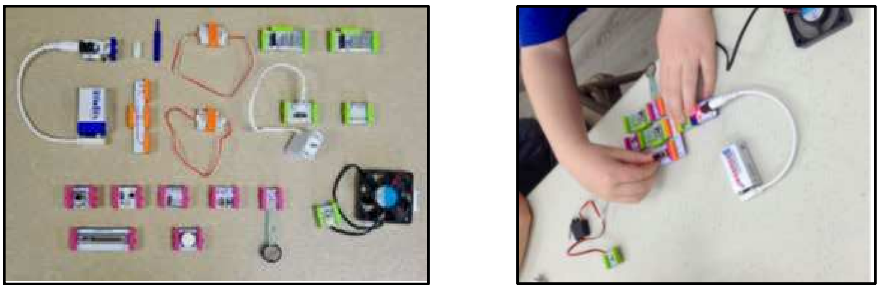
Methods

Building upon a three-year design-based research study constituted of four iterations, the study adopts the methodology of a qualitative case study (Yin, 2017) to investigate families' science imagination practices in two workshops in the last iteration. The case study method enables detailed examination of each individual families' interaction within their sociocultural context.

Setting

The study was carried out in two intergenerational meteorology workshops, which were held in a library and an environment center. The library and environmental center were in rural counties. The workshops were free and were advertised ahead of time to library patrons and environmental center members. The goal of the meteorology workshops was to engage families to work together to understand how meteorologists collect data to predict the weather by making connections to issues of concern to rural families such as farming, raising animals, and gardening.

During the meteorology workshop, each family was given a set of littleBits, which are magnetic prototyping tools that can be used to make battery-powered inventions. Each littleBits set included sensors (e.g., temperature sensor, pressure sensor, light sensor) and pieces like number display, fan, threshold, servo, wire, etc. (see Figure 1). Families then used the littleBits to prototype a weather station to help local community stakeholders. Each workshop was led by the same meteorologist. A typical meteorology workshop lasted about 70 minutes. Each family workshop consisted of three primary phases: 1) Families explored how littleBits work. 2) Families talked about weather variables that are important to collect to predict weather. 3) Families received a design challenge sheet with a farmer and a gardener's first-person narratives (see Table 1), and then each family created a weather station using littleBits.



(a) (b)

Figure 1. (a) A set of littleBits given to each family and (b) an example weather station in-progress.

Table 1: The two first-person narratives provided to families to guide their weather station prototyping

	Narrative content provided to families to support their weather station prototyping
Option 1	**Design a weather station for a local farmer:** I run an animal farm. I need to keep my animals cool during hot weather and keep them warm during cold weather. I also monitor rain and air pressure to keep my animals dry. I need daily information to take care of my animals, so collecting data on the weather is important. Can you make a weather station to help?
Option 2	**Design a weather station for a local gardener:** I have a vegetable garden. I need to plant veggies during cool or warm weather. I need to know about rain so I can make sure my plants have the right amount of water. I also need to know about wind so I can keep them protected. I need daily information to take care of my plants, so collecting data on the weather is important. Can you make a weather station to help?

Seven family participants
The workshops were open to families of at least one parent or guardian and one child aged 5 to 10. Families signed up for the workshops through partnering libraries and museums. In total, 7 families: 8 consented adults and 13 assented children, participated in the two workshops. These families represent typical users of informal spaces that are part of rural communities.

Video-based data collection
The data collection and analysis processes followed Derry et al.'s (2010) guidelines on video-based research. Family interactions were video recorded with 2-4 cameras set up in each workshop. Additional audio recorders were placed on tables to supplement video recordings of family talk. The data included 7.5 hours of video recordings, 2 hours of audio recordings, and 62 pages of content logs with transcripts of particular episodes.

Data analysis with interaction analysis and coding
To analyze the data, the study drew upon Jordan and Henderson's (1995) interaction analysis. After the first round of video viewing sessions, emerging episodes related to families' collective scientific imagination on meteorology in the weather station prototyping event were identified across families. Those episodes were then transcribed for each family. Relevant gestures and actions were included in double-parentheses in the transcripts.

Interaction units — which comprise of one or multiple sequential utterances and actions where one or more persons in the activity convey an idea, a thought, a comment, a statement, or a question — were used to conduct a more fine-grained analysis of families' talk and interactions. The interaction units were coded using four categories emerged from iteratively reviewing the videos and the theoretical framework:

1) technology (i.e., identifying littleBits pieces or figuring out how littleBits work),
2) weather imagination (i.e., imagining weather phenomena, tools, or scenarios),
3) weather-related scientific concepts or processes (i.e., how weather phenomena is formed) and
4) narrative (i.e., referring to the farmer or the gardener's narratives).

Looking specifically at imagination practices, a weather station representation map was created for each family. The map aligned the littleBits pieces that families used in creating weather stations and their imagined phenomena and situations in order to compare families' imaginative practices.

Findings
Overall, technology-related interactions occurred the most within families, followed by interactions related to narrative, imagination, and scientific weather concepts or processes (see Figure 2). When using littleBits to create weather stations, families most frequently explored the functions of different pieces of littleBits and talked about how the pieces connected to or reacted upon one another. In addition, technology-related talk and interactions often started a new sequence in which families brought up a new idea or comment.

Weather imagination and narrative-related interactions typically occurred after technological interactions. For example, in one family of a mother, a father, a daughter Soraya (aged 9), and a son Abe (aged 9), three types of interactions—technology, imagination, and narrative—coupled together in a sequence where they discussed the usage of the light.

Mother: What you can do with the light? ((points)) [*technology*]
Soraya: So that they (farmers) can check in the middle of the night. [*narrative*]
Abe: Or if there's storm clouds moving in. [*imagination*]
Mother: Oh! Storm clouds moving in, it's darker. Oh sunshine! I didn't even think of that. [*imagination*]

The data also shows that parents' participation also affected the frequency of different types of interactions. For example, one family, with the dad not being involved in the activity, only talked about littleBits' functions and organization without talking about the narratives or imagining different weather phenomena. Parents, compared to children, referred to the farmer/gardener narratives more to prompt children's design and imagination. On the other hand, even though all families mentioned key weather terms such as air pressure, rain, wind, temperature, etc., only two families discussed how certain weather concepts like air pressure forms different weather phenomena.

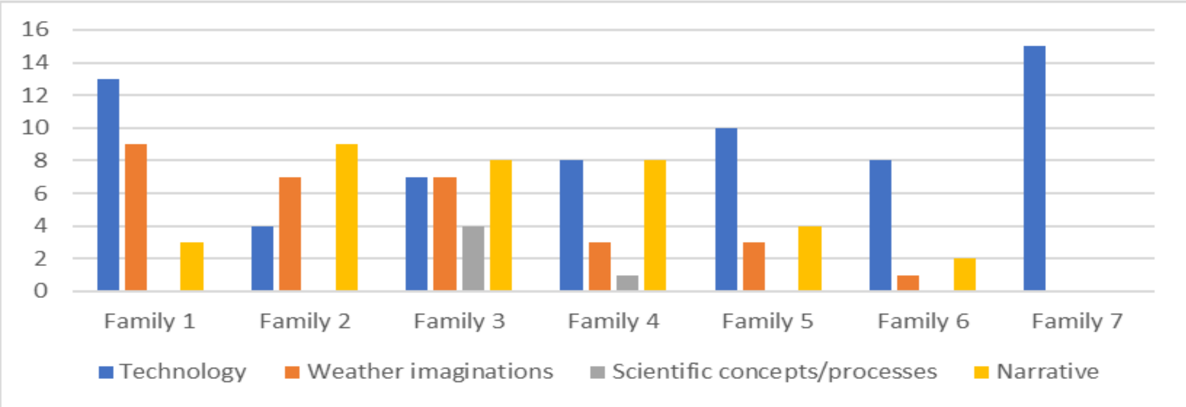


Figure 2. Types of interactions occurring within families.

Material and cultural affordances of artifacts shaped meteorological imaginations

As shown in the weather station representation map (see Table 2), families chose similar littleBits to create their weather stations, but they imagined weather in different ways. A common trend that was seen among families' design of weather stations was that families imagined weather phenomena through linking the physical characteristics of artifacts (i.e., littleBits) to their experiences in their rural community and knowledge of weather.

Families were more likely to make imaginations around littleBits pieces that generated visible reactions. For instance, wind, tornado, and anemometer were some common imaginations that families made when adding the fan into their weather stations. Families also touched and played with the fan or tried placing it at different spots on the weather stations to imagine the possible usage of the fan. For instance, one family engaged in shared imagining around fan and wind:

Father: What about this guy ((takes up the fan))? Do you use this to measure anything?
Soraya: I think you could do the wind speed.
Mother: Wind speed. Oh is that... I thought it's a thing that's sort of like? ((spins finger in the air))
Father: I think it responds to signal. ((moves around pieces)) So, if we put that here, we might be able to measure speed.

Even though the fan in littleBits could only function to move air, instead of measuring wind speed, all families that included a fan in their designs envisioned that they were using the fan as a tool such as an anemometer that can detect wind.

Table 2: Weather station representation map of 7 families at the two sites

Family (pseudonym- age/parent)	Primary littleBits pieces used in weather station	Imagined weather phenomena or tools
Eliya (7), Rianna (9), Calen (Father)	light sensor pressure sensor button fan button + fan	changing sunlight wind blowing rain hitting on a surface wind blowing wind
Anthony (9), Cassius (6), Evangeline (Mother)	pressure sensor + number servo + wire + battery lights sensor + dimmer	wind weather data collection system detect temperature change
Abe (9), Soraya (9), Amir (9), Maurelle (Mother), Marquise (Father)	light sensor light sensor + threshold pressure sensor fan	clouds and sunlight storm alarm storm wind and anemometer
Judy (11), Jeannie (Mother)	fan light sensor	anemometer sunlight
Ripley (9), Nikko (5), Joy (Mother)	fan	tornado, tornado warning system, wind
Brayden (6), Milo (Father)	fan	wind
Leonard (9), Conrad (8), Walter (Father)	pressure sensor	none

Exploring the material features of littleBits triggered families to imagine weather in distinct ways. For instance, when using the pressure sensor, some families talked about how it could collect air pressure data, while other families envisioned different imaginative scenarios around it. For example, one family discussed how the pressure sensor could measure imagined wind's speed, which families accomplished by pressing on the sensor with their fingers:

Father: This is just pressing actually on the thing ((presses the littleBit pressure sensor with his fingers)), so it measures that amount. I don't know if that's going to be the right thing if we are measuring rain.
Eliya: It could be for measuring *wind*!
Father: Oh! You think so?
Eliya: Measuring wind... Yeah. cuz *the wind could push this down* ((presses the sensor with her fingers)). (see Figure 3)
Father: So, the wind is pushing on it?
Eliya: Yeah, it can show you *how fast the wind is* ((presses the sensor harder)).

In this case, the 7-year-old daughter, Eliya, did not use the pressure sensor to measure air pressure as other families did, she thought of wind instead. Eliya's perceptions of wind were manifested in the ways in which she coordinated her body towards the sensor to envision the force created by the blowing wind. In another sequence where the family discussed ways to measure rain, Eliya suggested using the button: Constantly pressing on the button and tapping on her father's arm (see Figure 4) to imagine measuring rain, she said, "the rain could like *press down on here*, the rain could *push down on here* and show you how fast the rain is going down".

Figure 3. Eliya imagines wind pressing on the sensor.

Figure 4. Eliya taps on father's arm while imaging rain.

Eliya also mentioned, "If it's (the rain) really hard, it kind of hurts the plants". In this case, regardless of the practicality of using alike tools to detect weather, Eliya was able to bodily foreground the physical characteristics of rain through connecting to her experience and knowledge about how rain interacts with the world. Eliya's body, her experience in weather, and the littleBits became resources that enabled her to imagine wind and rain.

Imagination-enabled science representations that reflected scientists' practices

As observed in the data, imagination, when mediated by the littleBits prototyping artifacts, shaped families' science representations. When families were selecting what littleBits they wanted to use to *represent* weather data collection tools, they not only imagined the possible weather phenomena that could be detected with the device but also envisioned how *scientists study meteorology*. Three families talked about using littleBits to create tools more than just measuring wind, rain, or air pressure; they mentioned using pieces like lights sensor, fan, servo, and threshold to create meteorological tools such as a *tornado warning system* or a *storm alarm*, which are tools built and used by meteorology professionals. For example, Anthony, a 9-year-old boy, designed a data system to observe and predict weather. Anthony, explained to his mother how different littleBits could collect data and then he imagined how the data would travel through the different parts of a weather database housed on a computer:

Anthony: Oh! ((takes up the servo littleBit)) This could be a *signal*! This could be like a power signal thing ((attaches it to the weather station)).
Mother: Anthony, what are you working on in the middle?
Anthony: A little weather thing ((holds up the servo)), like *tracks the weather* and all the *data* goes in here. Once it *senses it*, and it will go through here ((points at the power wire and the battery)) and it goes through- and I'll have another wire here, and it will go through here and there's the *computer* ((points at different spots around the weather station)), so it has all the data. (see Figure 5)

Figure 5. Anthony explains his design of a weather data collection system to his mother.

Here Anthony built an imaginary situation by naming, organizing, and pointing at the real and imagined artifacts, (e.g., servo, signal, computer, wire, data). He demonstrated his knowledge and perception of how weather is studied professionally as he inscribed the imaginary artifacts into his representation of the weather data system.

Narratives designed in the workshop prompted children's imagination

As observed in the data, the narratives provided in the curriculum (Table 1) prompted children's imaginations in different ways. Sometimes, the narratives did not support learning in the ways in which the curriculum was intended to be used.

It was observed that most parents read out the community stakeholders' narratives or referred to the narratives several times during the activity to help their children think about how they wanted to design their weather stations. The farmer and the gardener's narratives encouraged families' to imagine weather and what tools they could design to measure weather. However, with the community stakeholders' needs presented in first-perspective narratives, sometimes children focused on how the devices that they designed could help the stakeholders take care of their animals or plants instead of using the tools to help them predict weather. For example, Abe, a 9-year-old boy, suggested adding the fan to "keep the animals cool" and his sister, Soraya, mentioned using the light sensor to help farmers "see in the dark". The children imagined the real-life situations of how a farmer raised animals and their needs. In this case, imaginations were used in both sequences to design a product but were not targeted on weather prediction.

Discussion and significance

The findings from seven families at the two meteorology workshops illustrate that littleBits, families' experience in weather, and community stakeholders' narratives materially and culturally influenced how families imagined and represented weather phenomena and scientists' practices in weather forecasting. Families engaged in various imaginative interactions depending on how artifacts, actions, talk, and prior knowledge orchestrated in their interactional, sociocultural context. When examining the interplay of the technology, imagination, and narrative talk, we found that families most often engaged in imaginative and narrative-based talk after their engagement with the littleBits components. For instance, Soraya and her family imagined wind after exploring the fan and a sensor for storm cloud detection after exploring the light circuit. This suggests, for the families in this workshop, that engagement with technology bolstered youths' imaginations during the workshop. Given that families on trails at a nature center also engaged in imaginative play when learning to use new cultural tools (magnifying lenses, binoculars), the present analyses reinforces that imagination is a key factor in learning to use new cultural tools in science. Building from the prior work of Stratford and Low (2015), we posit prototyping tools (such as littleBits), can also help adults and children to engage in imaginative practices to learn about meteorological data.

Echoing Cole's (2017) theory on cultural artifacts, the dual material and conceptual characteristics of littleBits artifacts brought families' knowledge and experience associated with weather to the current experience. The shapes and the functions of littleBits, and how they were selected and pieced together, shaped families' imaginations on weather; their imaginations then inscribed new meanings to the artifacts used, which further shaped the ways in which science was represented. This aligns with Vygotsky (2004) and Zittoun and Gillespie's (2016) perspective on how imagination can expand one's experiential boundaries and connect science to the real-world. Through imagining with littleBits and the narratives, they were eliciting their experience in *feeling* the weather to express their understanding of weather phenomena that are not easy to see (Ingold, 2005; Stratford & Low, 2015).

As revealed in the analysis of families' interaction units, families paid much attention to the material elements of the prototyping tool. However, it should be noticed that while technological tools shaped and supported families' imaginative practices, technological exploration did not always lead to imagination and discussion of scientific concepts or processes. More research can be done in designing artifacts and curricula to expand children's imaginations on weather phenomena, and to connect them to more complex meteorological concepts and processes.

Expanding on the literatures on science representations, families' everyday knowledge about weather forces acted as *constructive resources* (Azevedo, 2000). Their knowledge of weather was embodied in their bodily interactions with the artifacts (i.e., Eliya acting out the rain) and the process of creating science representations. Also, as shown in the data, families imagined how scientists *do work* in a particular field and incorporated such imagination into their representations (i.e., Anthony imagined building a weather tracking database). As creating science representations is viewed as an important skill for science professionals, it is worth deeper exploration in the role of imagination in scientists' creation of presentations and how children's imagination could be leveraged to engage them in scientists' practices.

The findings also show that first-person narratives included in the weather curriculum triggered families' imaginations in varied aspects. Originally, the narratives were designed to provide families a problem scenario that connected them better to the local community that they lived in. However, the imaginations associated with the narratives were not always related to meteorology but sometimes the stakeholders' needs in farming or gardening. In those cases, the narratives supported families' design process, but did not guide families in talking about weather phenomena or making weather predictions. Thus, our analyses suggest that narrative is a productive tool for supporting imagination; we suggest additional research to investigate how the community stakeholders' narratives could support or hinder families' learning in science in other settings and content areas.

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