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Connecting children's scientific funds of knowledge shared on social media to science concepts

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ABSTRACT

The ubiquitous use of social media by children offers a unique opportunity to view diverse funds of knowledge that may otherwise be overlooked. We have iteratively designed a social media app to be integrated into our science learning program which engages families in science in their community. This case study highlights how three focal learners (ages 9–14) revealed scientific funds of knowledge through social media sharing. Their teachers noticed occasional funds of knowledge in the children's posts that they could connect to formal science concepts. However, other scientific funds of knowledge were not obvious by observing the posts alone. Rather, these latent funds of knowledge emerged through our triangulation of posts, interviews and observations of their learning experiences in our life-relevant science education program. Our findings suggest implications for the design of technology and learning environments to facilitate the connection of children's implicit and more unconventional scientific funds of knowledge to formal science concepts.

1. Introduction

Social media (SM) presents an opportunity to unobtrusively access learners' funds of knowledge because children commonly use SM to capture and share life experiences [1]. As educators gain access to a live stream of children's everyday experiences through SM, they gain opportunities to facilitate personal connections to academic learning [2,3]. However, educators are uncertain as to "what counts" as legitimate forms of learning and literacy through SM [4]. Recent studies have found that although both teachers and students are willing to use SM for education and believe it will enhance the educational experience, they rarely incorporate SM into their education practices [5,6]. In science education, one reason for educators' hesitation could be that they miss scientifically relevant ideas embedded within children's SM posts because they are unfamiliar with the social and cultural experiences that children share and the ways in which they share them. How can we understand the interaction features and connected practices that illuminate children's scientific funds of knowledge in SM sharing?

Our study is situated in a life-relevant science-learning program, called *Science Everywhere*, designed to help children connect science to everyday life [7]. The *Science Everywhere* program leverages a SM app to facilitate scientific inquiry that we have iteratively designed over the course of a 5-year design-based research project [8,9]. Through this process, we have learned that giving children SM tools allows them to share science learning in personally, socially, and culturally relevant ways [2,10–14].

Our work builds on prior research on SM and learning. Much of this work has examined how youth leverage SM tools for learning (e.g., using *Facebook* to form study groups or ask classmates about homework) [4,15]. Our efforts focus on supporting scientific inquiry specifically with SM tools. We have developed several iterations of SM prototypes, and have evidenced how such tools can help children with different participation styles and interests contribute to science inquiry learning environments in new ways and overcome interpersonal conflicts in face-to-face environments [2,12]. However, one limitation and gap in our previous work was that we piloted the tool in a single constrained setting: an informal learning program that was designed for children [2,12,14]. Thus, we were only able to see what children chose to share in that *single* context. *Science Everywhere* builds on prior iterations of our design-based research process to understand SM sharing *across* multiple settings (i.e. home, neighborhood, in-school, and after-school). In this study, we equipped children with

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mobile devices, installed the current iteration of our SM app, and asked them to share as they went about their everyday lives in different settings. Therefore, children were able to capture and share a wider range of experiences that they related to science.

Our case study explores the rich personal, social, and cultural connections that three focal learners make to science from their everyday contexts when they have ongoing access to SM tools and scaffolding for connecting science to everyday experiences. We use funds of knowledge [16,17] as a lens to recognize the aspects of science children expressed in their SM sharing so that we could see children's implicit and more unconventional scientific knowledge.

In the context of the *Science Everywhere* ecosystem, this study explores the affordances of technology and learning environments that illuminate scientific funds of knowledge, particularly in non-dominant communities where scientific funds of knowledge have a higher likelihood of being overlooked due to traditional educators' lack of familiarity with diverse cultural idioms, practices, and vernacular [18,19]. We explore the question, **"What information about scientific funds of knowledge can be gleaned through social media sharing?"** We found that often, learners' funds of knowledge were not evident in the posts alone; rather, they emerged through our triangulation of all data sources (i.e., interview transcripts, field notes).

By exploring interconnections between the scientific funds of knowledge that educators readily recognized through the affordances of the *Science Everywhere* SM platform and those that were missed by SM sharing alone, we deepened our understanding of the diverse ways in which children express scientific funds of knowledge in SM across contexts. We leverage our emerging insights of these cross-context possibilities to develop design implications for both the design of SM technologies for STEM learning and the design of learning environments that leverage SM tools. Therefore, our study also addresses the question, **"What are design implications to connect funds of knowledge that children share on social media to scientific concepts?"**

2. Background

Research on funds of knowledge guides our analysis of the life-relevant connections children are making with SM tools. We also draw on literature investigating the use of SM in teaching and learning in order to consider design implications that facilitate how educators and parents recognize and respond to scientific funds of knowledge.

2.1. Funds of knowledge

Our study examines how children bring their everyday language, practices, and ways of knowing when engaging in science learning. Education researchers have suggested the need to place more value on the funds of knowledge that children bring to science learning, so that children can begin to realize the connections between their own lives and more formal scientific practices [20]. Such connections could support learners' efforts to develop scientific dispositions [20]. Building paths to facilitate such connections is particularly important for non-dominant learners, who experience increased tensions and divergences across their home, community, and school science cultures [18,19]. For example, tensions between the language of home culture and the language of science can create a conflict for underrepresented learners [19]. Furthermore, educators may struggle to recognize and attend to students' funds of knowledge because they are unfamiliar with the language and/or experiences of students from cultures different from their own [21].

Moje et al. [16] identified four major themes of science-related funds of knowledge: *family, community, peer,* and *popular culture*. First, "family scientific funds of knowledge" are family practices that are or can be connected to science learning. For example, some families practice the process of sweating chilies, which connects to formal science concepts of condensation and evaporation. Second, "community scientific funds of knowledge" are activities tied to ethnic identity and social activism. For example, the community in Moje et al.'s [16] study advocated for better air quality in response to high asthma rates, which connects to medicine and environmental science. Next, "peer scientific funds of knowledge" are activities that children engage in with other children. For example, some children connect to physics concepts of force and motion when riding bikes around their neighborhood. Last, "popular cultural scientific funds of knowledge" are activities inspired by music, movies, and games trending in local communities and broader society. For instance, in Calabrese-Barton et al.'s [22] study, young girls remixed a popular song to describe each of the bones in the skeletal system. Overall, Moje et al. [16] identified many connections between students' everyday/community practices and formal scientific concepts.

While science educators have explored strategies to attend to and value funds of knowledge in science learning [7,16,17,21,23–25], they are often unable to employ these strategies due to curricular or time constraints in the classroom [17]. There is a need for educators to develop strategies to access and attend to students' funds of knowledge in a more personal, pervasive, and sustainable way, which we explore in this study.

2.2. Technology for science learning

We aim to strengthen the connection between formal scientific practices and learners' everyday experiences through SM sharing. The *Next Generation Science Standards* (NGSS) define science practices as authentic scientific activities such as asking questions, planning investigations, and interpreting data [26]. These practices are sometimes challenging to incorporate in formal teaching and learning due to lack of time, resources, and/or teacher knowledge [27]. Collaborative technologies have sought to alleviate some of these obstacles by facilitating children's scientific practices in informal and formal learning environments [28,29]. For example, Knowledge Forum (KF) includes software that facilitates its users' collaborative construction of conceptual models [29]. Web-based Inquiry Science Environment (WISE) provides individual scaffolding in topic-based modules and online discussions to facilitate the conceptualization of scientific phenomenon [28]. Design interfaces for science learning have also focused on scaffolding and mobility [30,31]. For example, Zydeco facilitates nomadic inquiry between museum and classroom contexts while scaffolding the formation of formal scientific argumentation [31].

While these systems effectively scaffold science learning and investigation, they provide less support for the exploration of personal aspects of scientific inquiry, such as creativity and curiosity. Just as new media literacy studies have shown that children often practice and express their literacy skills in informal and unconventional ways [6], studies in science discourse have demonstrated that children may express their efforts to engage in science in unconventional ways that do not resemble more formal discourse typically valued in science classrooms [18]. Indeed, youth engaging in popular interactive media such as massively multiplayer online games have demonstrated scientific habits of mind in their online gaming forums [32]. To leverage the rich potential of SM for helping youth, especially non-dominant youth, connect personally to science, we therefore need to better understand how children express their funds of knowledge and, more specifically, scientific funds of knowledge, in SM.

2.3. Social media for youth learning

We draw on SM tools to support learners' connections to their funds of knowledge. Children commonly use the mobility of SM platforms to capture and share experiences across different contexts (e.g. home, school, community). As such, these technologies have potential to "collapse contexts" by facilitating interactions between teachers, students, parents, and community members [1]. Identifying the rich connections learners share on SM is a prevailing challenge when leveraging digital media to promote literacy and science learning. Education researchers have found that a primary pedagogical reason that educators are hesitant to use SM in their classrooms is that it is unclear if and how the practices students engage in through SM connect to more formal academic practices [15]. Furthermore, adults sometimes believe they understand what they see through children's SM sharing without considering how the child imagined the context or meaning when they posted the photograph or comment [1]. While a number of studies have investigated the use of different SM platforms in teaching and learning, the literature provides little guidance on best practices for integrating SM into pedagogy and learning [6]. Exploring best practices for SM integration in education is a crucial first step to using SM with frequency and purpose in teaching and learning.

Many different SM platforms have been developed and implemented in teaching and learning such as Facebook, Ning, MySpace, Edmodo, and Space2cre8 [6]. In this study, we utilize the SM platform *Science Everywhere,* which is a tool that has been iteratively designed to support children's efforts to capture and share scientific experiences from their everyday lives. However, this study does not focus on the innovation of *Science Everywhere* as a SM tool. Instead, we aim to discern how we can understand ubiquitous SM sharing to design new tools that signal where children's funds of knowledge occur in informal, unconventional, or tacit ways, and to propose options for integrating these funds of knowledge more explicitly into science learning.

2.4. Social media for science learning: Science Everywhere

The *Science Everywhere* application was developed through a participatory design process [14,33]. Children and parents worked together to design software that would help them to learn about science together, capture scientific moments in their everyday lives, and share those insights with other users. During the design process, researchers analyzed the ideas from parents and children, compared suggestions, and continuously iterated upon the application design. An overarching goal since the conception of the first prototype has been for users to capture and share the funds of knowledge that they bring from everyday life experiences.

Science Everywhere builds on prior work to leverage children's everyday use of SM sites and engage them in life-relevant science experiences by expanding beyond our designed learning contexts [2,10–14]. We found that to effectively integrate children's personal funds of knowledge in science learning, we must also support their flexible use of community-based science tools *across* home, neighborhood, in-school and after-school contexts [14]. We designed *Science Everywhere* with the specific goal to have learners share scientific experiences with their entire community (e.g. peers, parents, community leaders). To achieve this, we designed *Science Everywhere* as a browser-based application so that users could access it on any device (Android, iOS™, laptops, tablets, Chromebooks) without needing to download the app.

In *Science Everywhere,* users make "posts", which may consist of pictures, screenshots, text and/or emojis. They may select a

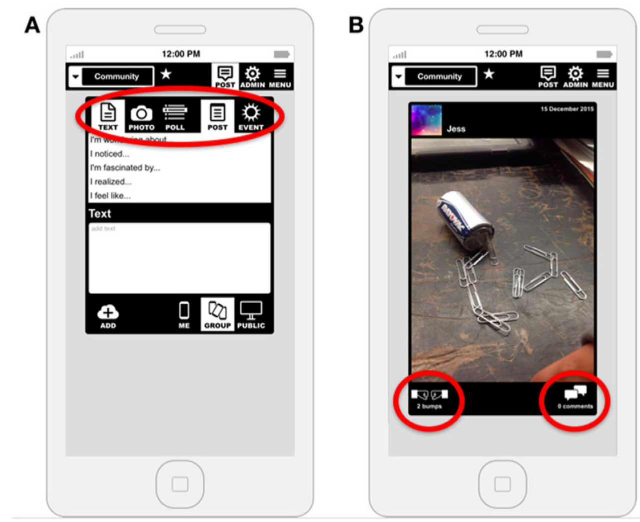

Fig. 1. Screenshots of the Science Everywhere app. A. Making a post. Multimedia features allow text, photo or poll inputs. B. Home screen is a newsfeed of all user posts. Users can award a "bump" to a post or comment on each other's posts.

sentence starter such as "I'm fascinated by" to begin writing about their post (Fig. 1). To support learners' social experiences on the app, these posts are displayed in a newsfeed and other community members can respond to posts with a comment and/or emoji. Additionally, users can acknowledge a post with a "fist bump", which is similar to a "like" on other SM platforms (Fig. 1). To protect the children's privacy, the site is restricted only to participants (e.g., parents, children, mentors, informal educators) in the physical *Science Everywhere* community.

3. Methods

3.1. Contexts and settings

Science Everywhere is an informal learning program implemented in two different urban locations in the United States — one in the Mid-Atlantic region and another in the Pacific Northwest. Participants in the program include elementary, middle, and high school students (6–16 years old) from Title I schools in the local community. There is a wide age range for program participants because of our focus on families, who often have children with large age differences. The program was originally formed through tight connections between formal and informal contexts in a local neighborhood. Researchers, teachers, and community leaders comprise our *Science Everywhere* research team and serve as facilitators and active participants in our design-based research process [8,9].

During the school year, *Science Everywhere* facilitators hold weekly after-school meetings that focus on helping youth engage in scientific inquiry in the context of everyday life. For example, participating children and facilitators tackle broad science-related questions and topics, such as "How do different ingredients result in altered textures, tastes, or chemical reactions in food?" or "How do airplanes work?" or "What are the principles of flight?" or "How do the lights in my house work?" As part of their participation in the program, children receive iPod Touches loaded with the *Science Everywhere* app, which enables them to capture the investigations that they conduct during program sessions as well as any questions or comments they may have for the community throughout their day. Specifically, the *Science Everywhere* app allows children to post text and pictures and comment on and interact with others' posts [33]. During meetings, we encouraged children to share their ideas, findings, questions, and insights on the app. The *Science Everywhere* research team also pose several take-home "challenges" throughout the year to inspire children to post about scientific concepts and practices from their everyday life. We recognize the contributions of the children with an embedded badging system and frequently discuss posts with groups of children during our weekly meetings. We encourage learners to use the platform to share scientific experiences and engage in scientific practices with other community members, even if they feel their ideas are ill-formed and exploratory [34].

3.2. Participants

In the *Science Everywhere* informal learning environment, six researchers, one science teacher, and two community leaders served as facilitators and moderated student participation on the app. Eighteen ($n = 18$) families, including 40 children/youth (ages 6–16) and 14 parents, regularly participated in the program. Most participants were second-generation immigrants and all families came from underrepresented backgrounds.

Our study focused on the Garcia (pseudonym) family, comprised of a mother, a father, and four children: Emma (pseudonym) (14 years old, 9th grade), Kayla (pseudonym) (13 years old 8th grade), Jax (pseudonym) (9 years old, 4th grade) and Cassie (pseudonym) (4 years old). At the time of our study, the youngest sibling was too young to participate in the program. The Garcia family is very proud of their Hispanic heritage. Both parents are immigrants from El Salvador and everyone in the family speaks fluent Spanish. The community in which they lived had a large Hispanic presence. Emma, Kayla, and Jax participated in the *Science Everywhere* program for 3 years. The family regularly attended the weekly after-school meetings, often being the first to arrive.

The science teacher of each focal learner was recruited over email with consent from the focal learners. Ms. Sorrel (pseudonym) was Emma's high school Honors Biology teacher. She is an African American woman in her forties who had taught science for fifteen years. Mr. Spinach (pseudonym) was Kayla's seventh grade science teacher. He is an African American man in his sixties who had taught science for twenty years. Ms. Leek (pseudonym) was Jax's 4th grade teacher. She is an African American woman in her forties who had taught for two years after a career change.

3.3. Data collection

The *Science Everywhere* team collected data for over three years, September 2014–September 2017 All participants contributed to our overall corpus of data. This includes video and audio recordings of the weekly sessions; field notes by the research team; posts that participants shared on the *Science Everywhere* SM app, interaction logs from the app, artifacts created by participating children, parents, and facilitators (e.g., artwork, notes, and designs handmade by children during weekly sessions). Program participants were selected for semi-annual interviews that focused on different aspects of their participation, such as the types of posts they made (as in the study reported in this paper), or contributions they made to the participatory design sessions. Overall, the project collected video, artifacts and field notes from over seventy-five science learning sessions. Participants have made around 2100 posts.

We chose to focus on one family as a case because understanding the social, cultural, and personal histories of how the content that they share in a given moment came to be is essential for understanding their funds of knowledge. In order to understand how the users' SM sharing reflected their funds of knowledge, we follow them over time and across settings. Each step of our data collection process is detailed as follows.

First, to gain insight into a wide variety of potential scientific funds of knowledge that children may share on SM, we selected ten posts from each focal learner that represented a variety of locations, interests, peers, and content. For instance, we selected posts that included questions the children had or observations they made while playing at home or while on family outings. Most of the posts we focused our analysis on were created outside of *Science Everywhere* sessions, as we are particularly interested in the types of self-initiated scientific inquiry children may engage in when they are not in school or informal learning settings. In many cases, these posts may be inspired by informal learning programs or classroom activities, so they are good candidates for shedding light on connected learning practices that children may be trying out. We also analyzed field notes from *Science Everywhere* meetings between September 2014–September 2017 for any mention of the three focal learners, particularly comments that might offer insight into their posts, potential scientific funds of knowledge, and their use of SM. Each focal learner was specifically mentioned in the researcher field notes of at least twenty-five sessions.

Second, the focal learners and their parents were interviewed in order to explore the funds of knowledge they wanted to share in their posts, how they articulated, explained, and recognized these funds of knowledge [20], and how they might connect them to science. We conducted two interviews, each approximately 30 min in duration. During the interviews, we asking them about their family, heritage, hobbies and interests. Then, we showed each focal learner the pre-selected posts and asked, "Why did you share this post? When and where were you when you shared this post? What were you doing when you shared this post? Is this post related to being a designer, investigator, or engineer? If so, how?" During the interview, we also invited the children to select other posts that they were especially "proud" of, then asked them the same questions. We showed parents of each focal learner the pre-selected posts and the posts the learners were proud of and asked, "Where was this post taken? What was happening in this post? Do you see evidence of science learning? If so, how?"

Finally, we interviewed each of the science teachers about each of the three focal learners in order to gain further insight and explanation about how each teacher recognized scientific funds of knowledge on social media, and if these perceptions aligned with the perceptions of the parent and the child. We first asked each teacher a series of questions in order to explore what funds of knowledge their focal learner shared in class throughout the academic year. The second part of the interview asked each teacher to look through his/her focal learner's posts and describe the individual posts that s/he thought would be examples of science learning, posts s/he noticed, and posts s/he found surprising. Last, we asked the teacher if they saw evidence of science learning in the pre-selected posts, and if/how they might leverage content from the posts in the classroom.

3.4. Data analysis

We adhered to the methods and standards of a case study [35] of one family with three focal learners in the Mid-Atlantic *Science Everywhere* program. We chose this family for several reasons. First, they have participated in the program for four years, since its inception. Importantly, the focal learners represent different age groups and each child has created a substantial number of posts across multiple contexts (i.e. *Science Everywhere* meetings, school, home, community).

We used an iterative qualitative coding process to analyze our diverse corpus of data. Initially, our analysis was framed broadly by known categories of funds of knowledge (i.e., family, community, peer, popular culture, as in Moje et al. [16]). Overall, however, we adhered to a grounded theory process [36], inductively developing themes in response to our research questions that highlighted the connections between the topics and knowledge children wanted to share, the affordances that enabled them to share them, and the explicit or tacit scientific practices that emerged from the posts and/or interviews.

As part of our analysis process, we compiled all of the data sources specific to each post as an interrelated set. For example, if field notes elaborated on the context for a selected post, we included these notes along with interview comments from parents and children about the post in our corpus for analysis. All of the post-related data sets were entered into a spreadsheet-based codebook specific to each focal learner. This approach facilitated comparisons between post-related content and also across post-related sets, enabling a systematic triangulation process throughout several iterations of coding. We followed a constant comparative process [37], noting thematic patterns between the interrelated interview excerpts (parent, child and teacher), SM posts, and researcher field notes within a set, then comparing themes across different sets, and finally comparing themes across each focal learners' data [37,38].

In our first round of coding, the research team inductively coded several illustrative examples of posts to generate themes related to the scientific funds of knowledge learners shared. Two researchers analyzed each set of focal learners' posts. Each researcher first individually coded the posts. Then we discussed coding discrepancies in a whole team meeting. Ultimately, the research team generated the themes "Topic of Post", "Context", "Location of Post", "Scientific Practice [26,27]", and "What was missed in the post alone", which were applied in a second coding pass to each of the selected posts. We defined scientific practices using the Next Generation Science Standards [26] and Chinn and Malhotra's [27] framework for identifying scientific inquiry practices. We cross-checked these categories and coordinated pairs of researchers together to analyze the data in order to maintain validity. Throughout our coding process, we ensured any additional overall coding discrepancies were not missed with periodic whole team review meetings. Finally, we compared and contrasted the funds of knowledge that were apparent in the post alone and what was missed without insight from other data sources. Design implications for both the learning environment and technology were suggested based on common themes for scientific funds of knowledge that were apparent and missed in multiple posts for each learner.

4. Findings

Based on our analysis of all data sources, we found that all focal learners created posts that hinted at information about their scientific funds of knowledge. Indeed, science teachers saw several opportunities to integrate learners' posts with meaningful science content and practices. However, some connections to scientific funds of knowledge were not obvious by observing the posts alone. In the next section, we present illustrative examples of the scientific funds of knowledge that were recognized by teachers and elaborated through interviews and field notes. We share how each science teacher recognized these posts as learning opportunities, and then propose implications for how the technology and learning environment could be designed to facilitate social media sharing as seeds for science learning.

4.1. Emma

Emma (14 years old, 9th grade) frequently posted on *Science Everywhere*. She enjoyed cooking, sports, and drawing in her free time. Her 9th grade biology teacher, Ms. Sorrel was an African-American woman in her 40s that had been teaching for 15 years. She said Emma was an "exceptional student". However, she also noted that Emma rarely volunteered in class and did not share personal things. Occasionally Ms. Sorrel called on her, but only regarding academic topics.

In the *Science Everywhere* app, Emma shared posts about cooking, the environment and her everyday experiences from home and the community. In these posts, she asked questions, conducted investigations and made observations. Frequently, when considering the posts in isolation, the context, motivation behind Emma's post, and types of scientific concepts she wondered about were not apparent. Emma explained such details in interviews, showcasing greater depth of scientific funds of knowledge. Without additional information gleaned from the interview, we missed opportunities to make richer connections to her emerging scientific funds of knowledge. Examples of such posts are presented in Fig. 2.

In Fig. 2A, we see that Emma shared a picture of a pizza that she made. As soon as Emma saw this post she exclaimed, "*It was the first time I ever attempted at making something like this from scratch*". Her father recognized this as the time she made pizza at the house (family funds of knowledge). She went on to describe that it was part of an experiment she was doing for *Science Everywhere* as part of a learning sequence focused on the chemistry of cooking. She explained, *"I shared this post because I was proud of making the pizza".* Connecting the post to the kitchen chemistry learning sequence, that was going on in the Science Everywhere program at the time, allowed Emma to recognize the scientific practice of conducting investigations. The feelings she expressed in the interview, such as how proud she was of this experiment because it also represented a successful and autonomous experience with baking, highlighted emotions that were not apparent in the post alone.

When Ms. Sorrel observed this post, she inferred that Emma was sharing something she had made for her family. Without hesitation she recognized Emma's post as an opportunity for scientific learning. Ms. Sorrel explained, "Chemical reaction and the fact that you start with certain reactants and you end up with certain products… I like to use the example of baking a cake. You put things in and get things out". Although Ms. Sorrel had no knowledge that this pizza was connected to a scientific investigation as part of an after-school science program, she recognized seeds of science learning in the post [3].

As she observed the posts, Ms. Sorrel noticed that Emma shared more on *Science Everywhere* than she did in class. She explained that Emma may have shared more because she was more comfortable sharing virtually, "It seems as if she's more open and maybe it's because she doesn't have to do it in person, get up and stand in front of people, she can do it behind a screen". Another explanation Ms. Sorrel gave for Emma sharing more personal information in *Science Everywhere* was because "it's actually requested for by the after-school program". Ms. Sorrel may not have prompted students for personal information, and Emma did not volunteer any details in class. After viewing Emma's posts, Ms. Sorrel seemed inspired to prompt connections between science concepts and everyday experiences. She explained her idea, "after each concept in class what we could do is tell the kids to go out and take a picture of a real-world event that related to this concept". She continued to write her idea down on a piece of paper to remind herself later. She explained that making those explicit real-world connections is one of many tools that you can use to enhance the learning experience for kids.

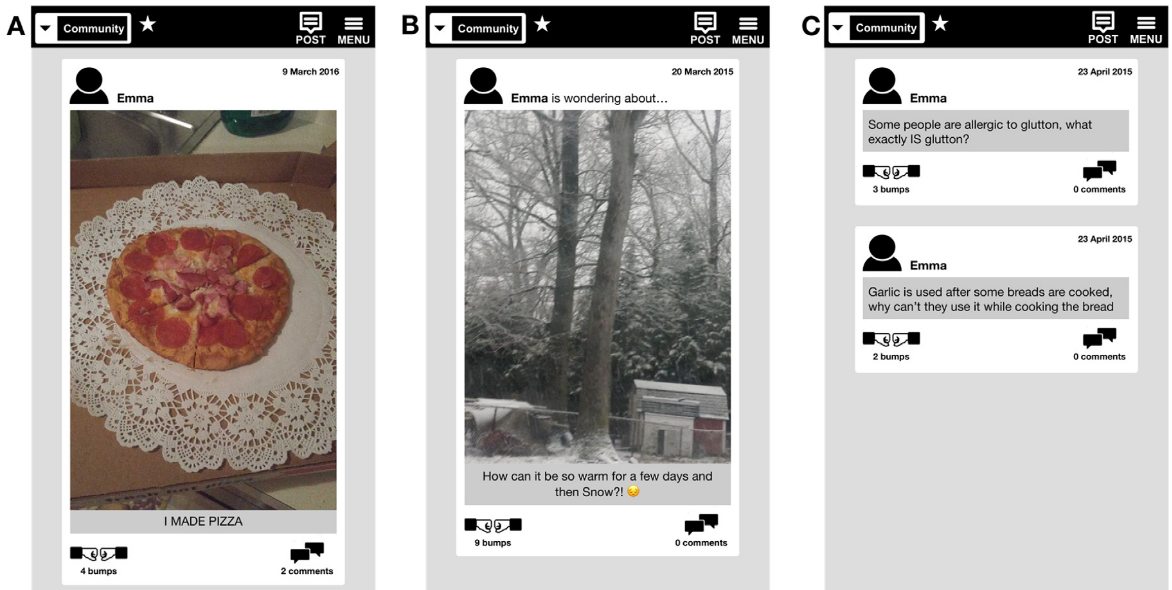

Fig. 2. Illustrative examples of posts from Emma.

4.2. Kayla

Kayla (13 years old 8th grade) was a regular participant in our *Science Everywhere* program. She enjoyed art, especially designing and drawing in her time outside of school. Her 7th grade teacher, Mr. Spinach, taught Kayla during her science class (approximately 1.5 h every other day) during the 2015–2016 school year. He was an African American man in his 60s and had been teaching science for 20 years. Mr. Spinach explained that Kayla was a quiet, focused, and respectful student in class. She was creative and imaginative and loved art projects. Her work, written and visual, showed a certain level of healthy appreciation for her work product. However, she was "very introverted" and rarely shared anything in class, whether personal or academic. He explained, "She will not volunteer in class — she needs to be asked. Sometimes I didn't know if she was getting the concepts or not because . . . she doesn't engage during discussion". He went on, "Even though she didn't talk very much, I could always tell she was thinking…that's why I wish she shared more". Although she was engaged during class, she struggled with "content and vocabulary" on tests, and often did not earn very high test scores. He explained that he had a hard time supporting her in class because a number of other students in her class had behavior challenges. He described, "That has been a concern I've had for many years — how do we reach kids like Kayla that are quiet, particularly in very distracting environments?"

Although Kayla did not frequently share her ideas in class, she did share experiences on the *Science Everywhere* app. Kayla created designs, asked questions and conducted investigations/projects at home (e.g. home improvement, cooking/baking) (Fig. 3). She also shared animal observations, such as rabbits in her community and a birds' nest near her house. Through interviews with Kayla and her family, we gleaned information about the location of her posts and details of the investigations/projects she was conducting.

For example, she shared the construction of a house in Fig. 3A, which she calls "minecraft [sic] in real life". Kayla's post was made immediately after a learning sequence in the *Science Everywhere* program focused on designing cities in *Minecraft* (popular culture funds of knowledge). She stated that "*I was really proud of it because I can show people that you can create some of these things in real life*". When her father saw this post, he explained that this was a shed that he built in their backyard (family funds of knowledge) [16]. This post suggests that Kayla was connecting the engineering and design practices in *Minecraft* to the engineering and design practices of building a shed. While this post captures a snapshot of the construction, further engineering practices could be recognized if she had been able to share the *process* of constructing the shed at different time points.

When Mr. Spinach saw this post, he immediately recognized a connection to computer modeling. He explained, "Here she is taking the abstract, something she created in the computer-generated setting, and trying to create a model of it". Although Mr. Spinach did not know this was a shed her father was constructing at her house or about the Minecraft *Science Everywhere* learning sequence, he acknowledged that Kayla was engaging in the scientific practices of modeling.

Similar to Emma's teacher, Mr. Spinach acknowledged that Kayla shared more on the social media app than she did in class. He explained, "She doesn't always share in class, but she is with the technology". In fact, he seemed to be impressed with the amount that she shared, explaining, "I already knew she was creative and that she has an innate curiosity… I guess that I didn't have an appreciation for the breadth of her curiosity". He also discovered that she "has a really strong interest in nature" when observing her posts. Mr. Spinach saw potential for application of the *Science Everywhere* app in his classroom. He thought that the app encouraged students to be "open to asking questions, and not always having the answer". He said ideally, the questions that the students ask could be the inspiration of a sequence of inquiry-based instruction. Mr. Spinach expressed that this type of learning would prepare his students for their adult lives because it would encourage them to take risks and learn from their mistakes. He expressed that the high stakes testing environment inhibits this type of learning because it emphasizes one correct answer and "shuts kids that ask questions down".

4.3. Jax

Jax was a very active participant in the *Science Everywhere* program. He almost always volunteered responses in front of the whole group. Jax frequently shared a variety of posts from the *Science Everywhere* app and his everyday life. He expressed an interest in scientific experimenting and sports, especially soccer.

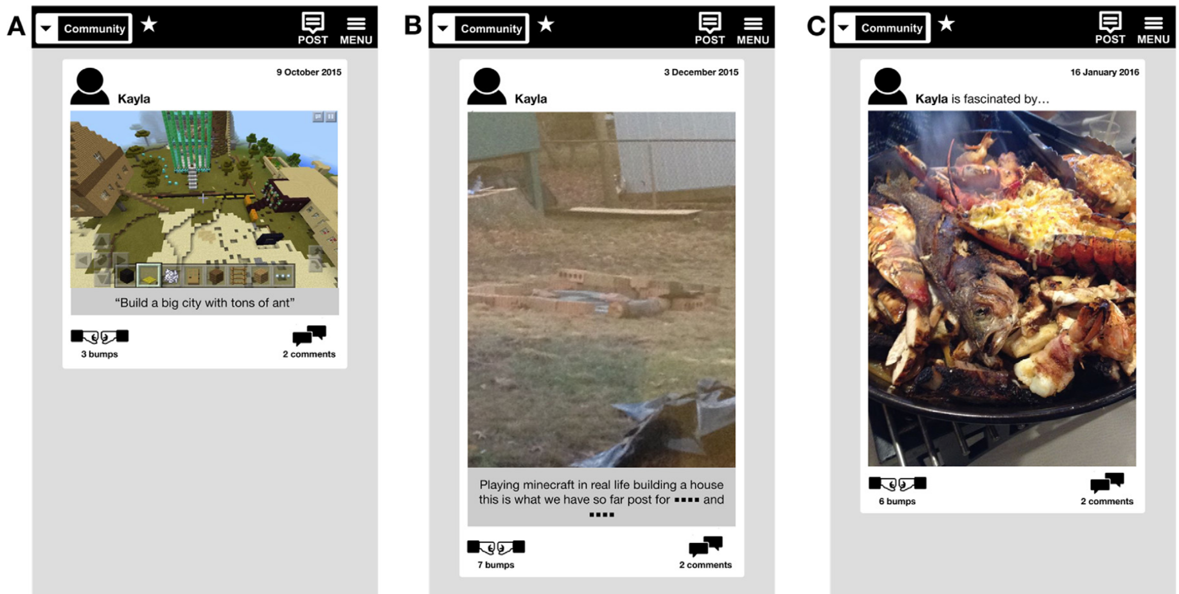

Fig. 3. Illustrative examples of posts from Kayla.

His 4th grade teacher, Ms. Leek, is an African American woman in her 40s who had been teaching elementary school for 2 years after a career change. She indicated that Jax was an energetic and enthusiastic student in her class. When asked to talk about Jax, Ms. Logan lit up, "Jax is excitable", she explained, "he loves to learn … I love his enthusiasm". She went further to explain, "he talks a lot. You have to cut him off sometimes. Other students need an opportunity to talk". While Jax "always" shared his ideas in class, she expressed that he doesn't typically talk about topics outside of school.

In the *Science Everywhere* app, Jax frequently shared posts about experiments he conducted at home and sports. In his posts, he posed questions, captured the investigations he conducted and designs he engineered (Fig. 4). Frequently, we missed the personal and meaningful connections of Jax's posts by observing the posts alone. For example, what did he hope to accomplish by completing an investigation? How was this post significant to himself and/or his family?

In Fig. 4A, Jax made a post about attending a professional soccer game, asking how the stadium seats were constructed. In his interview, Jax's father explained that this particular game, El Salvador versus Argentina, was an important game to the family because they were from El Salvador. When asked about the post, Jax explained,

> I've seen videos where it took days and days and months and they had to use these big trucks to like staple, tape and super glue them to the ground. These were these special seats that were made out of something slippery plastic so I had plastic seats before but these were really slippery so I could slide down easily.

Jax's interview revealed that his design question was inspired from such videos (popular culture funds of knowledge). His excitement about attending a soccer game was evident and based on interviews and interactions with him in the *Science Everywhere* informal learning program, the research team knew that soccer was Jax's favorite sport (peer funds of knowledge) [16]. The post's connection to Jax's El Salvador heritage (community funds of knowledge) [16] became apparent through the interview with his father, who was very disappointed El Salvador lost the game the family attended. Through this data, a richer picture of the connections Jax made across contexts emerged, demonstrating how he accessed his community and popular culture funds of knowledge to develop scientific questions about designing and building a soccer stadium.

As Ms. Leek observed this post, she said, "That's definitely science because you talk a lot about measurements — you have to measure the field in order to get the right dimensions to build the field". Although she did not know the context of this post, she still noticed and confirmed that Jax was engaging in scientific practices.

After observing Jax's posts, Ms. Leek said she didn't learn any new things about Jax because he has such an extroverted personality. In fact, she said, "I'm surprised that's it … I'm surprised he didn't have a car with all the pieces on the ground with his goggles on". Still, after observing the ways in which the app supported Jax's efforts to connect multiple funds of knowledge with his natural scientific curiosity, Ms. Leek saw potential for using the app in her classroom. She imagined that it could help students collaborate virtually and help them to make processes more explicit, explaining:

> A lot of times we show them the final product, but we don't show them how we created it. A lot of children can't understand how it's done but once you show them through the pictures It helps them to learn that there are different ways of doing things.

She expressed that seeing examples from each other, and *how* these examples came to be, could spark more creativity in her students.

5. Discussion

This study contributes another link in an emerging chain for learning sciences and HCI designers that integrates literature on technology for science learning with SM for learning [2,10–14]. Previous literature on science learning with technology has primarily explored the design and implementation of cognitive scaffolding through more structured interfaces such as Knowledge Forum, WISE and Zydeco [28,29,31]. In addition, prior literature on SM for learning has primarily explored how existing platforms are used in classrooms and is centered around ways

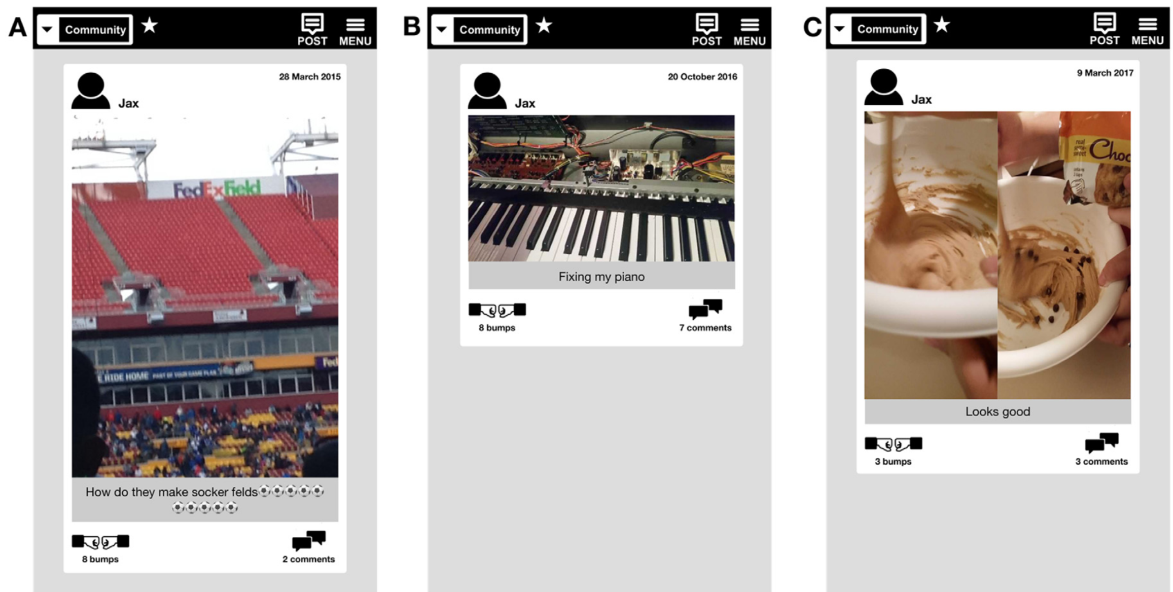

Fig. 4. Illustrative examples of posts from Jax.

children engage in specific formal learning practices (e.g., homework, assignments, etc.) [6]. Furthermore, there is little guidance on best practices for social media integration in teaching and learning [6]. Our study suggests the affordances of social media, in conjunction with connected practices, can be a powerful tool to facilitate connections between formal science concepts and learners' everyday experiences. These findings contribute to an understanding of how to leverage learners' informal experiences in formal settings. This practice is crucially important as sociocultural learning theories explain that an essential component of education is to forge connections *between* scientific concepts and students' home, community, social lives [4,39].

The questions that our focal learners developed are based on their personal, individual curiosities and on topics that are both relevant and meaningful to their families (e.g. building a shed) and community (e.g. soccer fields) [27]. It is critical to note that these implicit connections would have been more difficult to identify if the learners did not have the SM app that afforded them the opportunity to share their questions and thoughts in the first place. These implicit connections to scientific funds of knowledge are well-situated to be used by educators, facilitators, parents, and others to further a learner's scientific practices, but they first must be made more explicit to both the learner and their communities. While prior work illustrated that children shared science in personally, socially, and culturally relevant ways through SM [2,10–14], our study suggests that as learners share *across* multiple contexts there is a need for interaction features and/or connected practices to foreground the specific connections learners make between science and their personal, social, and cultural experiences.

In this study, we found that the learners were making rich connections between their everyday funds of knowledge and their efforts to engage in scientific inquiry; however, their efforts to engage in inquiry were not fully apparent. One of our study's goals was to explore the funds of knowledge that a diverse group of learners can demonstrate explicitly through SM platforms. We found that scientific funds of knowledge within the posts often show implicit and tacit demonstrations of science inquiry. While the teachers of these focal learners recognized the science learning in these posts, they could not fully appreciate the breadth of funds of knowledge [16] the learners were sharing (i.e. family funds of knowledge in Kayla's dad building the shed or the El Salvador soccer game). In this section, we propose implications for the design of technology and the learning environment to facilitate connections between the funds of knowledge learners share on social media and the science concepts they are experiencing across contexts.

5.1. Design implications for learning environments

5.1.1. Develop protocols to ask children about their posts in productive ways

Although our study suggests that children's scientific funds of knowledge are not necessarily made explicit through SM sharing, their posts provide the seeds to start conversations with children about how/why they shared these posts. Our interview protocol utilized open-ended questioning, such as, "Why did you share this post?" "When and where were you when you shared this post?" "What were you doing when you shared this post?" "Is this post related to being a designer, investigator or engineer? If so, how?" This line of questioning helped us glean the more richly contextual and connected information that led children to make their posts. Parents and teachers could use similar question sets to help them recognize the scientific funds of knowledge learners share from their everyday lives. Ahn et al. [40] found that parents and community members may need scaffolding to support children's outside of school science learning. Our analysis provides specific questioning techniques that might be useful for helping community members to draw out personal connections that learners are making *across* contexts to science. These practices are particularly important for more reticent learners [2] or non-dominant learners who are less likely to identify as scientists [18,19].

5.1.2. Prompt children to connect formal science concepts to everyday experiences

After an educator recognizes a connection between funds of knowledge and formal scientific concepts, it is helpful to prompt children to make these connections. *Science Everywhere* facilitators often posed challenges to prompt this type of sharing, and learners from the *Science Everywhere* program often chose to share posts that were anchored to the investigations they designed in the *Science Everywhere* informal learning program. For example, several posts from the focal learners were related to experiments about kitchen chemistry (Fig. 2) and engineering and design in Minecraft (Fig. 3). Ms. Sorrel saw potential to use an app like *Science Everywhere* in her classroom to connect concepts she discussed in class to experiences children had outside of school. Prompting children to make these real-world connections explicitly may help them begin to recognize science more seamlessly in their everyday experiences. Clegg & Kolodner [7] call the practice of children recognizing science in their everyday life "scientizing" and argue that it is essential for children to build scientific dispositions.

5.1.3. Expand on the observations or questions presented in the posts to make a scientific investigation

Providing learners with the opportunity to develop personal questions in order to design investigations may encourage them to make connections between their everyday experiences and scientific concepts. Mr. Spinach said that ideally, the students' idea-sharing and question-asking on social media could inspire a sequence of inquiry-based instruction. Designing investigations to expand on children's natural questions may provide opportunities for children to engage in scientific practices and develop deep conceptual understanding of scientific phenomena. Social media may provide a safe environment for students to express these interests and curiosities, which the teacher may otherwise never have accessed. As noted in Ahn et al. [2], this is especially true in the case of reticent learners, such as Emma and Kayla, who were unlikely to share personal information with teachers face-to-face.

5.1.4. Allow and encourage some "non-science" posts

Often, the richest funds of knowledge were reflected in posts that on the surface seemed irrelevant to science. For example, the post of making pizza or building sheds (Figs. 2, 3) does not represent explicit, traditional science content. Yet, behind the scenes the children were making connections to science. In fact, the ability to make such posts through the *Science Everywhere* app may serve as a key motivator for learners to participate and develop awareness of scientific processes and designs in general. Emma expressed that she felt that participating in *Science Everywhere* has empowered her to explore some of her natural curiosities, such as cooking (Field Notes, 7/17/15). Therefore, if "non-scientific posts" are *not* allowed, we might miss some of the children's richest funds of knowledge and efforts to become scientific thinkers. Concurrently, we must develop ways to ensure that learners are continuously linking their posts to science. Designers must therefore consider how to scaffold science in a way that does not hinder the spontaneous and free form interactions that promote sharing funds of knowledge. Finding ways to engage regularly in conversations about how learners' posts relate to science is a potentially effective way to strike the balance between allowing for spontaneity and formal discourse. These discussions could potentially help learners feel comfortable sharing their ill-formed thoughts even before they meet their "science-y" expectations.

5.2. Design implications for technology development

5.2.1. Connect posts to other posts, community members, location and experiences

Learners' scientific funds of knowledge were more apparent when provided the opportunity to include contextual information, such as who they were with, where they were, and what motivated their post. For example, in Jax's soccer field post (Fig. 4), the ability to tag other community members may have enabled facilitators to help him extend and elaborate upon the nascent connections he was making between his daily life experiences and science. Including process-oriented features such as linking posts in a series or tagging posts to more formal science activities could enable Kayla to connect her *Minecraft* post (Fig. 3) to our *Science Everywhere* learning sequence on design in *Minecraft* and alert other users to contribute to or collaborate on her design. Similarly, design features could be added that allow Kayla to easily designate her shed building experience with her dad as a home activity that was inspired by our *Science Everywhere* learning sequence on Minecraft. Such contextual features could draw educator and facilitator attention to help Kayla reinforce her home activity as an authentic science practice. Overall, interaction features that enable more seamless, explicit connections to be made, such as tagging people and places, may facilitate the recognition of scientific funds of knowledge in SM sharing.

5.2.2. Nudging features

Just as a teacher might ask children about their posts to gain insights about their scientific funds of knowledge, nudging features [41,42] could automate this line of questioning, and may even promote connections to scientific concepts. Nudges, or just-in-time prompts, have effectively increased awareness of privacy issues, such as their intent to share content to the general public [41,42]. The app could include automatic ways to "nudge" or prompt learners whether a post is related to a STEM professional identity such as "designer, investigator, or engineer".

For example, if the interface had asked Emma this question after her post, "I MADE PIZZA!" in Fig. 2, she could have selected "investigator" and explained her experiment (typing the question she was investigating). If nudging could be tightly coupled with connection features such as a tagging locations and people, educators could gain insights from groups of students, such as a classroom, without the time required to ask each child about their posts. Automating this type of information collection may be particularly effective for reticent learners [2]. Of course, automating any collection of personal information would require protection of the children's privacy. The interface would need to be closed to trusted peers and adults and the information would need to be collected with the child's consent.

5.2.3. Allowing learners to share experiences through time

While the *Science Everywhere* interface allowed users to post across contexts (e.g. home, school, community), design features that enable users to share experiences over time (e.g. slow motion, time-lapse) may illuminate or help children articulate the temporal qualities of scientific processes in the posts that they share. For example, giving Kayla the ability to document the process of constructing the shed in the backyard could have prompted her to capture the pictures necessary to show that her image sequence represented the engineering-related construction of a shed (Fig. 3). Additionally, Emma could have been prompted to take images of the steps she took to bake her pizza, better illustrating the scientific investigation she was conducting (Fig. 2).

5.2.4. Support integration of media for expressing emotions

Including design features that enable learners to share their emotions may help educators and facilitators notice personally meaningful funds of knowledge that are ripe for connections to science. boyd [1] referenced features of SM sites youth enjoyed, such as personalizing their *MySpace* page or *Facebook* profile. More recently, Clegg et al. [43] found that free-form integration of media helped children to share personally meaningful aspects of scientific inquiry. Our study has indicated that some of these customizable features could reflect their funds of knowledge, such as cultural funds of knowledge or peer funds of knowledge. For instance, Jax could have shown that the soccer game was El Salvador versus Argentina with a sticker of an El Salvador flag, highlighting the cultural pride in his heritage (Fig. 4). Additionally, he could have drawn on his post that he was curious about the construction of the seats, engaging in the scientific practice of asking questions (Fig. 4). Design features that allow learners to highlight personally meaningful aspects of experiences could facilitate awareness of "teachable moments" that educators may build upon to connect to formal scientific concepts. Interaction features such as stickers, emojis, and drawing tools may help children express scientific funds of knowledge in more personally meaningful ways.

6. Conclusion

This study provides suggestions for how to leverage children's ubiquitous use of SM to gain insight into children's funds of knowledge that may not be readily apparent at first glimpse. The SM sharing of the focal learners in our study illustrated connections, processes and emotions that were relevant to scientific practices and disposition development. While our focus on a single family limits our ability to make generalizations across learners and communities about how children from different backgrounds share scientific funds of knowledge, we have shown the complex interactions and challenges that exist even with a small cohort of motivated learners. Additionally, the information we were able to glean from the focal learners in our study was limited to the current sociable affordances of the *Science Everywhere* app (e.g. posting, commenting, bumping). Our findings suggest that some newer affordances of social media, such as tagging and stories, may better enable teachers to access funds of knowledge through social media sharing. Additionally, interaction features, such as tagging and nudging, may facilitate teachers to recognize and build on these aspects of scientific funds of knowledge by allowing users to make connections to people, places, and events. Our findings suggest that SM sharing in conjunction with other practices, such as prompting learners to discuss their posts and encouraging non-science posts, can uncover the rich contexts of children's SM sharing and illuminate their scientific thinking. In addition, employing a suite of technologies can expand the available channels in which children express and share their funds of knowledge. It is possible that adding the affordances and diverse audiences of other platforms, such as large displays, may also raise our awareness of the scientific connections young learners are making in their SM posts. Although this study focused on uncovering scientific funds of knowledge via posts from the *Science Everywhere* app alone, our overarching research program includes a broader technology lens that includes designing public displays to illuminate science in communities through SM sharing [40]. Future research should explore the intersection between the design of technology and the connected practices that support children's use of SM for learning. The affordances of SM may spur learners to make connections between formal science concepts and everyday experiences. Therefore, educators should consider leveraging SM and related activities to help children to apply what they are learning in their own personal contexts in new ways.

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Conflict of interest

No author associated with this paper has disclosed any potential or pertinent conflicts which may be perceived to have impending conflict with this work. For full disclosure statements refer to https://doi.org/10.1016/j.ijcci.2019.04.003.

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