Capturing Personal and Social Science: Technology for Integrating the Building Blocks of Disposition

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Abstract: The development of a scientific disposition opens opportunities for youth to see science as relevant in their daily lives. Four building blocks promote disposition development: gaining *competence*, sparking *curiosity*, belonging and contributing to one's *communities*, and bridging *personal connections*. In this paper, we explore the role technology played in supporting unified disposition development by detailing the experiences of two focal learners. We found that technology can act as a boundary object that supports connections across the building blocks in integrated ways, and we include challenges and implications for design.

Introduction

To advance our nation's goal of "science for all learners" (Rutherford & Ahlgren, 1991), researchers note that it is increasingly important to help young learners develop scientific dispositions (e.g., Borda, 2007). The development of a scientific disposition opens opportunities for learners to explore potential roles that they can play in science, whether they choose to pursue scientific careers or to use science practically in their everyday lives (Barton, 1998). We define disposition as values of, ideas about, and ways of participating in a discipline that come frequently, consciously, and voluntarily (e.g,. Gresalfi, 2009). We focus on scientific inquiry as a disposition that will help learners explore their worlds, and we analyze disposition through the lens of scientific inquiry practices. To support learners' efforts to develop scientific dispositions, we must devise ways to help them move beyond abstract facts and phenomena, to extend their classroom experiences beyond the bounds of school (Bereiter, 1995). Specifically, we must enable learners to *scientize* their daily activities, which involves helping learners see the world through scientific lenses, and to integrate this vision in practical applications across the contexts of their everyday lives (Clegg & Kolodner, 2014).

To that end, we have developed *life-relevant learning environments* (LRL) that include programs and technologies designed to help learners to engage in science in the context of pursuing their own personally meaningful goals and to explore potential roles they can play in science. Kitchen Chemistry (KC) is one such LRL program, and is the contextual focus of this paper. KC is an out of school program in which learners engage in scientific inquiry through cooking. Technology has been widely used to support learners' scientific inquiry experiences and understanding (e.g., Barab et al., 2010). Additionally, the ubiquity and culture of technology in today's society, especially among youth (Madden, Lenhart, & Duggan, 2013) suggests that technology holds powerful potential for supporting personal and social applications of inquiry among youth. While technology has been effective at promoting the development of specific aspects of disposition individually, less is known about how technology might promote learners' unified experiences across these building blocks of disposition development. Particularly, we ask: 1) what role can technology play in supporting learners' integrated development across the building blocks of disposition? and 2) how can we design technology to support learners' unified development across the building blocks of disposition?

Background

Based on prior disposition research, we have identified four building blocks that promote learners' disposition development (Clegg & Kolodner, 2014): 1) procedural and conceptual understanding support learners' efforts to develop the *competence* needed to engage in scientific inquiry; 2) interest helps learners develop a *curiosity* about the world – a desire to learn more; 3) social interactions promote learners' engagement in *communities* of individuals who share similar interests as well as communities to which they can make contributions; and 4) personal connections help learners develop personal values for scientific inquiry and reasoning and a *commitment* to engaging in scientific inquiry. While there is a wealth of literature on promoting these building blocks individually, less is known about how we should integrate them into more unified scientizing experiences, and how learners' dispositions develop through more unified experiences. Our previous work in the KC learning environment has shown that LRL environments can be places where the building blocks come together to promote learners' scientific disposition development (Clegg & Kolodner, 2014). We now aim to understand the ways in which we can draw upon the features and affordances of technology to promote learners' unified experiences across the building blocks of disposition development.

Given the ubiquity of technology in children's lives, they are engaged in a multiplicity of personally relevant, technology-based experiences, such as gaming (e.g., Squire & Jenkins, 2003) and social media participation (boyd, 2009). Through these deeply personal and interest-driven experiences, learners participate increasingly in affinity groups (Gee, 2005), which foreground common interests over membership in more formal structures. Key to unifying learners' development in the building blocks of disposition is then helping them to connect their life-world subcultures to the subcultures of science (Aikenhead, 1996). One potentially transformative factor in helping learners make these connections is the creation and management of *boundary objects* (Star & Greisemer, 1989; Wenger, 2000), or artifacts, tools, and processes that help people from different communities collaborate in meaningful and productive ways (Star & Greisemer, 1989; Wenger, 2000).

Our design-based research efforts (Collins, Joseph, & Bielaczyc, 2004) over the past few years suggest that technology holds potential to be an effective boundary object for bringing disposition building blocks together. Our initial efforts in life-relevant learning focused on connecting learners' scientific inquiry practices (i.e., procedural and conceptual understanding) to their personal interests (Clegg et al., 2012). We found that certain affordances of mobile technologies (e.g., storytelling) can help learners mediate between their interests, personal connections, and scientific engagement to promote unique approaches to and expressions of science. Next, we used a social media tool specifically designed to support learners' collaborative scientific inquiry (Clegg et al., 2013). We found that technology can help diverse learners recognize common interests and build on the contributions of others, even in tense social environments, to facilitate productive social collaborations in science (Clegg et al., 2013). While this work suggests the potential of technology as a boundary object to bring together the building blocks of disposition, few studies exist that examine how technology can be designed and used to promote an integrated experience across the four building blocks of disposition.

Our Approach: Life-Relevant Learning

While previous work looks at bringing subsets of the disposition building blocks together, the question remains: How do we design technology to integrate all four into a unified experience? Existing technologies have attempted this integration, but tend to foreground procedural and conceptual understanding. This makes it less likely learners will *want* to pick up the tool on their own in experiences that are important to them. Our approach has been to foreground the personal, using it as a means of promoting further learning. We have done this through the design of (1) LRL technologies and (2) LRL programs.

Figure 1. Timeline view in ScienceKit.

One component of our work is designing a LRL technology - *ScienceKit (SK)* (Figure 1) - that integrates the affordances we have found useful for unifying learners' experiences across the building blocks of disposition. SK is a mobile and social app that allows learners to capture and share snippets of daily life – similar to social media tools such as Instagram – but frames these sharing practices through a lens of scientific inquiry. SK is designed to scaffold learners' scientific inquiry in their daily lives by enabling them to create micro-contributions to the inquiry process. In SK, learners create entries with their choice of photos, videos, text, or drawing. With these media, they develop questions, observations, experiment sequences, cause and effect claims, or "just because" entries. These entries are shared on a sequential, public timeline for everyone to view. Learners can then "star" contributions as a means of favoring them. We used SK in the KC implementation presented in this paper. In the initial sessions of KC, learners engage in *semi-structured activities,* becoming familiar with processes in measurement, data collection, and technology usage in the context of cooking experiments aimed to answer scientific questions (e.g., What do eggs do in brownies?). On *Choice Days,* learners are given opportunities to use what they learned to develop questions, hypotheses, experimental procedures, and data collection techniques for their own food investigation. They also make decisions about recipe modifications, controlling variables, data collection, and interpretation of their findings. We designed these experiences in KC to support learners' scientific practice through interest-driven experiences with peers and adults to support learners' development across the building blocks of disposition development.

Methods

For this study, we employed the methods and standards of a comparative case study (Yin, 2003). The case is a single 1-week summer camp implementation of KC. In this exploratory study, we focus on the role of technology in supporting learners' integrated experiences across the building blocks of disposition development as we highlight their experiences in KC. We focus this case study on two learners: DeMarco and Allen (all names are pseudonyms). We selected these two children for this study as a comparison between how technology can support scientific inquiry and disposition development in sociable (DeMarco) and reticent (Allen) learners.

Context and Data Collection

For this implementation of KC, we met as an out-of-school, summer camp program for four consecutive half-days (Monday – Thursday, 4.5 hours per day) in a lower socioeconomic status public school in the Washington DC metro area. Seven learners (9 to 11 years old) from the school participated in the program. Our KC implementation was comprised of eight adult facilitators, one of whom focused primarily on technical support. The first two sessions were semi-structured days and the last two were Choice Days. On Day 1, learners observed brownies made with different amounts of eggs and did an experiment with eggs, oil, and water to understand how eggs work in brownies. Day 2 involved a cookie experiment to test and explore the roles of different leaveners. On Days 3 and 4, learners chose new dishes to perfect and worked on their Choice Day investigations with facilitators. Each day we collected video recordings of all activities and discussions. Additionally, to understand learners' identity development as they participated in the program, learners created short *personal* reflection videos in SK at the end of Days 1 - 3 in which they responded to the prompt: "*Today, I was more like a ... Chef, Investigator, Scientist, A combination (tell us which combination you felt like), or something else (tell us what or who). Then, tell us what you did to make you feel like that.*" We conducted interviews with each learner on the third day of the program, focusing on their use of SK, their experiences in science, and their experiences in KC. Facilitators also recorded post-observational field notes of their experiences each day in KC. Lastly, we collected analytics (e.g., time stamps, account logins, SK posts) as participants posted contributions to the SK app.

Data Analysis

Our data analysis process included two phases. In the first phase, we analyzed data types individually. For each learner's personal reflections, we transcribed and conducted open coding (Corbin & Strauss, 2008) to identify themes for each learner based on the identity-related information they provided. Based on this analysis, we selected two focal learners with the most drastic differences in participation styles: very sociable to very shy. This comparison is important because participation styles play a significant role in learners' disposition and identity development (Clegg & Kolodner, 2014) and we want our tools and programs to support a diverse range of learners. Next, three authors coded the SK posts of the two focal learners, describing each media file and coding entries for aspects of learners' scientific practice based on Chinn and Malhotra's (2002) inquiry framework. We also coded for themes related to the types of interest-based, social, and personally meaningful experiences learners were having with the technology (Clegg et al., 2012). Finally, four other researchers built contextualized stories of each learner's experience in the program, using a combination of observation data (e.g., post observation field notes, video transcriptions). While SK entries represented snapshots of specific experiences learners had, contextualized stories provided a broader perspective of learners' daily experiences. The second phase of our analysis consisted of a collaborative analysis session in which all three data types were integrated. All researchers gathered and printed out each set of data (with media files from learners' SK entries and photos from the contextualized stories). We lined each learner's data sources up side-by-side sequentially to represent that learner's experiences with SK. The visual nature of our data enabled us to have an axial coding session in which researchers used sticky notes to create analytic memos that were grouped into major themes for each learner. We followed with selective coding (Corbin & Strauss, 2008), to identify themes across cases.

Findings

Here, we present the cases of each focal learner, DeMarco and Allen, organized by the themes underlying our research questions.

DeMarco: A Social Entry Into Science

DeMarco was a rising 5th grader who entered KC with a calm demeanor but took a social approach to scientific inquiry throughout the session. DeMarco's initial participation in KC involved using SK to take photos and videos of other learners in the program. During almost all whole group conversations, DeMarco recorded conversations with SK, moving the camera to record the speaker. DeMarco actively participated in these discussions, contributing thoughts and questions as he recorded. He began to ask questions in KC at breakfast on the first day. As the learners ate Apple Jacks™ cereal, a facilitator, Naomi, wondered if the cereal actually contained apples. She referred to the ingredients label on the container and was surprised to see that they did contain apples. Seeing DeMarco's interest in the question, Naomi encouraged him to create a question in SK. DeMarco then shifted from recording his friends at breakfast, to creating a video about the question they had, showing the ingredients label to answer the question. Later, during breakfast, DeMarco repeated this process of creating question videos when he heard another learner ask a similar question about milk. In his video, DeMarco displayed and read the ingredients label on the milk carton, then concluded that milk does not have sugar. He continued to ask questions about ingredients that he was interested in during the following days' activities.

Semi-structured Sessions: Scientific Reporting

DeMarco continued to take this reporter role in the initial sessions of KC. In this role, he documented and narrated the types of experiences they were having in KC, often interviewing group members about what they were doing. DeMarco's reporting became more scientific on Day 1 as John, the facilitator working with DeMarco's group, was careful to model the types of observations to make and ways to use SK to record observations. On his own, DeMarco took photos of their experiment variations, paying close attention to capture details about the variations in his photos (e.g., variation in ingredient quantities, before and after photos, etc.). As he made observations about their experiments, he also began to make predictions and claims based on those observations about the differences in the brownie samples, and how eggs work in brownies. DeMarco's reporter role also involved taking photos and short video clips that documented their individual experiment procedures, recording measurements of their cookie heights, and documenting their procedures for measuring.

Personal Science: Fried Chicken Experience

DeMarco worked with facilitator, August, to plan his Choice Day experiment. This was a very personal and scientific experience for DeMarco, and it involved significant social motivations for him in and out of KC. DeMarco's idea arose because he wanted to make the fried chicken his mom cooks at home. He expressed that she never let him in the kitchen and he thought she would be proud of him for making a complex recipe. Facilitators noted that it "made his day" to be able to make fried chicken. However, due to safety concerns, DeMarco's project also was a source of much consternation for the facilitators. These concerns were a great source of humor and helped develop rapport between DeMarco, facilitators, and other community members (like the school lunch lady – Ms. Carlitta). DeMarco's pride in this project was illustrated as he posted sketches of fried chicken in SK (e.g., drawing a chicken leg with a heart around it) during planning on Day 2.

As DeMarco engaged in his Choice Day project, two primary ways he engaged in scientific inquiry were: 1) experiment planning and 2) observing and analyzing experiment results. DeMarco worked with facilitators John and August to plan his Choice Day experiment. John suggested they fry the chicken in different oils to learn about the differences. The facilitators reported that he warmed up to the idea when he saw that they (the facilitators) were excited about it. He even brought his mom's olive oil on the first Choice Day (Day 3) to use in the experiment. They planned a 2 x 2 experiment that started with testing different chicken breaders (i.e., flour versus flour + egg wash) and oils (i.e., olive oil vs. canola oil). On Day 4, the group cooked each breader variation in different oils. As the group conducted different experiments, they had DeMarco observe and analyze the results in different ways, such as blind taste tests with the results with DeMarco describing the results as he tasted them. Facilitators reported that DeMarco was excited to see observable differences in the color and texture chicken fried in olive oil versus canola oil (regardless of breader variation). As DeMarco described the results of each variation of chicken, August created two graphs to visualize his results.

Challenges with Scientific Inquiry

Although DeMarco engaged in these scientific practices during Choice Day, facilitators observed that he still needed significant scaffolding to think of his fried chicken in a scientific way. The facilitators found it more challenging than previous days to get DeMarco to think scientifically in the context of such a personally meaningful endeavor. They had difficulty helping him move from opinion to more descriptive observation (e.g., moistness and crispiness as observable outcomes versus "it tastes good"). Additionally, August thought DeMarco was "a little lost" during the graphing exercise and more generally, less interested when they talked about the science. DeMarco's SK posts also demonstrate some of the challenges he faced engaging in scientific inquiry during Choice Day activities. Of a total of 107 entries that DeMarco created throughout the KC summer camp, only 16 of them were created on Days 3 and 4 (Choice Days). The Choice Day entries were primarily *recordings of* DeMarco by others and not entries *created by* him. Personal and social photos were taken of DeMarco, and science videos were posted of facilitators interviewing him about their experiment procedures.

DeMarco's Personal Positioning in Science

Although the facilitators noticed a decrease in DeMarco's interest in scientific inquiry during their Choice Day project, they observed a resurgence of energy and engagement during the children's oral presentations. In preparation for showing their parents, families, and the school community about their Choice Day experiences and products, DeMarco set up his presentation behind the librarian's desk. He used both the chicken he made and the graphs generated during their reflections to present his results to the community. He described to his audience the experiment they did and explained the results represented on the graphs with competence and gusto. Based on their data, he told his audience he would suggest to his mom a different oil to use in the future. In field notes, the facilitators observed the pride, confidence, and authority with which DeMarco presented his results. One facilitator noted, “He totally owned his graphs as he explained his results to others.” As DeMarco carried out his experiment, he received recognition from others in KC, his own family members, and the larger school community. Another facilitator noted that the other KC children often viewed a photo DeMarco posted to SK in which he posed confidently with his chicken, showing the gloves he wore as he prepared the fried chicken. Facilitators also noted that DeMarco “just beamed” as he presented his work to the broader community and received accolades not only from his siblings but also from others’ family members and the school staff.

Role of Technology in Promoting DeMarco’s Disposition Building Blocks

DeMarco’s technology use matched his experience in the physical environment. First, he used SK to document his *social* experiences in KC using videos. With modeling and prompting from facilitators, he began to use SK to express the *interest* he had in new questions and the observations (*procedural and conceptual understanding*) he made using SK’s integrated multimedia. While these observations were scientific in nature, many simultaneously reflected the social and playful experiences DeMarco had during KC. He referred back to these entries later in KC discussions as well as in his personal reflections as evidence for his participation as a chef and scientist. During Choice Day, he made contributions that expressed his *interest and personal connections to* making chicken (drawing, photos). He posted photos and videos that showed his engagement in the process. Although DeMarco also had scientific contributions during these highly personally experiences, his use of SK dropped significantly. However, the contributions he did create were widely viewed (on the timeline) receiving a total of 14 favorites, helping DeMarco to be recognized socially for his contributions.

Allen: Seeing Science Through the Lens of ScienceKit

In contrast to the social antics of DeMarco, Allen’s overall case narrative and associated vignettes reflect the ways in which SK supported a painfully shy learner’s efforts to develop his building blocks of scientific disposition. Allen often acted nervous and quiet, during whole group discussions and in smaller cooking groups. He was hesitant to talk unless explicitly prompted, even in one-on-one situations. When facilitators addressed him in small group settings, he wavered, often putting his hand to his head or mouth and delaying a response. At times, he did not speak at all, and would duck behind his iPad™ screen, as if waiting for the group’s attention to transition from him. Allen also appeared embarrassed about being “on camera,” particularly during his personal reflection videos or when other KC learners tried to record him. In their small groups, facilitators often observed Allen distancing himself from his group. Because of the ways in which he held back during small group activities, facilitators were concerned that he was not engaging in scientific inquiry. One facilitator’s field notes captured this sentiment with her hope that Allen would soon “put one foot in the experiment instead of none.”

The First Day: Connecting with Others through Minecraft

Although Allen was timid in his interactions with others, he appeared more focused and adventurous in his interactions with SK. During our initial review of facilitator field notes and learners’ personal reflections, it appeared on the surface that Allen did not evolve as much as we had hoped in terms of scientific disposition and inquiry practices. His silence and physical distance during small group interactions made it difficult to detect any overt progress. However, Allen’s SK data, corroborated by vignettes from the session videos, indicates that Allen did advance across several disposition building blocks, by participating through the lens of ScienceKit and the iPad™. Like most learners in this group, Allen immediately began by using SK tools to make sketches. Allen connected his initial forays with SK to his personal interests by drawing scenes and images about the game Minecraft™. One result of SK’s social media design was that Allen’s drawings were seen in the public SK timeline. One facilitator, Naomi noticed Allen’s drawings of “creepers” (characters in Minecraft™) and engaged him in a discussion about it. These small moments were important ways that Allen developed rapport and connection to the KC program, despite his outwardly shy persona.

Through the Eyes of Allen: ScienceKit as an Expressive Tool

As the week progressed – in contrast to his aversion to being recorded by others – Allen would sometimes talk, sing, or dance to his iPad™, in his own personal “selfie” SK videos. In one vignette, he made a short video of himself singing, “Here we’re cooking.” This example was corroborated both in SK data analysis and in our review of the session camera video that captured him standing apart from, and unnoticed by others working in the environment at the time. This was just one instance of several playful and focused connections he made to share his personally meaningful experiences through SK.

Perhaps the most compelling evidence of Allen’s efforts to connect personally to scientific inquiry were the sketches he made of his Choice Day experiment, which involved making s’mores, a marshmallow, chocolate, and graham cracker sandwich. In the beginning, Allen focused most of his energy on connecting personally to this project. Daniel, a facilitator, noted that because Allen was less vocal about his ideas than the other learners, his drawings often functioned as a communication tool throughout the planning and execution of his s’mores’ investigation. Many of Allen’s SK entries on s’mores were sketches, especially those completed as he and Daniel planned his experiment. For example, he imagined his s'more as a mythical Minecraft character (the "herobrine"), and included the written description, "they will look like a herobrine skin, lol, I am making s'mores." This entry proved to be one way in which he also tried to connect socially with Tonya, a facilitator, as she asked him what questions he wanted to answer with his experiment. In the video vignette, Allen located this entry in the SK public timeline and showed it to Tonya, after she had asked what s'more shapes he wanted to evaluate. He explained that his s'more was a "herobrine s'more," and he wanted to add eyes and a mouth. Of note, the square structure of a s'more echoes the pixelated block that is the base building unit in Minecraft. This interaction not only offers evidence of attempts by Allen to connect his personal interests to his scientific inquiry efforts, but also highlights his attempts to communicate this connection to others.

Allen's Scientific Dispositions through the lens of SK

Our session videos and SK data indicated that Allen was actively involved in documenting scientific procedures and making observations. During the semi-structured activities, he would take short videos of experimental steps (e.g., shaking water bottles), sometimes recording the procedure as he was taking part in it. He also took a photo of a brownie through a magnifying glass to show a closer view of its surface irregularities. Although we did not observe Allen recording measurements (e.g., the diameter or area of the s'mores), he made several SK entries of the other KC learners, with accompanying text. Thus, SK's image and video capture features enabled Allen to develop *procedural and content knowledge* aspects of his scientific disposition. Allen also used SK to make predictions or claims about experimental outcomes, and to pose questions about his observations. For example, when prompted, he contemplated reasons why different batches of brownies exhibited distinct textures. Of note, these SK entries contrast with his first day working in a KC group, during which time he did not verbally offer any explicit hypotheses or claims. In addition to scientific observations that Allen made during group experiments, he documented experimental results through SK. Sometimes he would capture one variation at a time in a separate entry until he had captured them all. At other times he would take photos of all variations or several at one time, looking across them. In one entry, he used SK to sketch "good" versus "bad" cookies by highlighting brown, burned edges for the "bad" cookies. Allen's active capturing in this pattern demonstrated his being attuned to the experiment at hand and comparing across variations.

Recasting Minecraft S'mores as Engineering

As noted earlier, Allen chose to make s'mores for his Choice Day Project. As his s'mores planning developed, he made SK entries that concretized his ideas, and helped him imagine variations that were both playful and engineering or design-based. For example, he imagined and sketched s'mores as a house, a jail, and a different Minecraft character. His SK sketches became increasingly more engineering and design-oriented after his experiment. For example, one SK entry reflects a workflow how-to reference for assembling s'mores: "cracker → cracker + chocolate → cracker + chocoloate + marshmallow" (note the sequential arrows as visual cues). He also continued to practice other dispositions in his Choice Day project. For example, he took photos comparing the different s'mores ingredients (e.g., baker's chocolate versus milk chocolate bars) and evaluating his finished s'mores. From an overtly social perspective, however, Allen still hesitated when carrying out tasks and making decisions, despite the fact that the s'mores investigation was his Choice Day design.

Finding a Niche in KC

Over the course of the week, Allen earned a social reputation and identification as an experienced iPad™ user. Facilitators would point toward Allen's iPad™ use as an example of best practices (e.g., switching his iPad™ camera lens). Fellow learners sometimes asked him for help, or followed his (mostly silent) lead. In contrast with his engagement in the physical environment and activities, during which he hesitated or made mistakes because he did not inform facilitators or ask timely questions, he was meticulous about his SK entries. In one video vignette, Allen's longest unprompted discussion with facilitators (~3 minutes) occurred because he had a question about how SK loaded media onto its timeline. He was frustrated that some of his work might be lost due to delays in loading media, or server crashes. In response to Allen's thoughtful, designer-oriented concerns, Daniel suggested that he record his question as a design idea for future iterations of SK, and Tonya recommended that he confer with Michael, the SK developer who could attend to his ideas more deeply.

Role of Technology in Promoting Allen's Disposition Building Blocks

While facilitators had difficulty seeing Allen's scientific disposition develop in person, our analysis of his SK entries and video data revealed a different story. We observed evidence that Allen used SK to begin to make personal connections to science-based KC activities, increase his procedural awareness of scientific inquiry (e.g., making observations), and to initiate social connections in ways that he could not have done without a technology support like SK. Allen connected with SK as he first used it to relate to his *personal connections* (drawing and Minecraft™). He continued to develop this relationship as he had expressive moments with the iPad™ not observed by others. He used it to connect to *scientific inquiry practices* as he meticulously documented his observations and experiment procedures using SK's multimedia capture features (photos, videos and sketches). Not only did Allen document scientific elements when prompted, he also documented personally meaningful aspects of his scientific experiences. Furthermore, he described and articulated his *interest* in making s'mores through drawing, and used SK to communicate with facilitators about his ideas. In this way, SK served as a mediator for Allen's social interactions.

Discussion: Boundary Encounters and Objects

Science education literature establishes that science learning is a matter of border crossing between multiple communities (Aikenhead, 1996). In fact, learners transition between sub-cultures of home, school, peers, and media everyday. Their engagement in science learning is a matter of becoming enculturated into the customs and practice of scientific inquiry (Aikenhead 1996). Participating in KC can thus be seen as a boundary encounter for learners – a place where they were confronted with the idea that cooking and science were related and valued activities. KC was an environment where learners were introduced to a form of social and interest driven science that seemed new to them. Allen and DeMarco's initial hesitance to share their own ideas suggests that this was indeed a new form of science engagement and learning for them. The people, processes, and norms in KC were quite different than school (e.g., working with researchers, cooking, coming up with new scientific ideas to explore). Promoting learners' development across the building blocks in this context thus required helping learners connect to a new community socially, personally, and scientifically. It also involved helping them connect their participation in outside communities to their participation in KC in meaningful ways.

Role of Technology in Disposition: ScienceKit as a Boundary Object

Boundary encounters are facilitated through boundary objects. We conjecture that SK served as a boundary object that could potentially enable multiple building blocks to be integrated into one tool for many different types of learners. The diversity of Allen and DeMarco's participation styles shaped different life-world connections and scientific progressions for each of them. DeMarco connected to scientific engagement through first linking it to his social practices and home values, while Allen first connected SK to his interest and personal connections to the gaming community of Minecraft™.

Wenger (2000) discusses three types of boundary objects for connecting diverse communities: processes, discourses, and artifacts. We found that SK served as an artifact within the environment that helped learners connect different aspects of their participation, and also influenced the processes and Discourses of the environment. Learners developed norms of use (processes) for using SK that included taking on the role of reporter to document what was happening *socially* and *scientifically* in the environment, and capturing their own *interests* and *scientific engagement*. These norms also included scrolling through SK to see what others were doing. Learners' continuous browsing through SK enabled DeMarco to be recognized *socially* for his contributions in KC by others early on and later as others continuously viewed his contributions to SK. SK also shaped the language of science (Discourse), helping it to become more *personal* and *social* with multi-media and social media features. As an artifact, SK served as a repository of learners' experiences that helped us to see Allen's previously unnoticed participation and those that DeMarco often referred back to during his personal reflections. The repository represented this new form of social, personal, and interest-driven science by integrating the four building blocks of disposition through its technical features.

Design Implications and Challenges for Disposition Development

Even as an effective boundary object, some aspects of SK presented challenges for learners, educators, and designers. DeMarco's case showed that in boundary spaces, if learners move too far over into one building block (e.g., personal connections), it can be more challenging to motivate their scientific participation. DeMarco's case suggests that boundary objects may be more effective at integrating the disposition building blocks if designed to foster additional connections to broader communities (e.g., family, peer, or media) that are motivating audiences for learners. For example, future iterations of SK could include a means for learners to share self-selected media artifacts outside the local KC community (e.g., with family). Allen's case reveals another boundary space in which learners participated – the space between the virtual and the physical. SK primarily supported Allen's integration of the building blocks in the virtual environment. However, he needed more help with social interests in the physical environment, particularly with respect to social interactions and being recognized. His case illuminates the potential to use data and analytics from applications like SK, to help make educators and others aware of learners' participation. These in-situ data snapshots can strengthen our awareness of the link between learners' virtual and face-to-face participation, and suggest opportunities for authentic, formative evaluation of disposition development.

Conclusion: Contributions of This Work

The work presented in this paper contributes to our understanding of how to promote disposition development with technology. We appropriated common media sharing features of social media in the design of SK. By allowing children to capture and share their daily experiences, through a lens of inquiry, SK helped learners integrate the disposition building blocks in ways that began to promote learners' comprehensive scientizing experiences. This analysis suggests that viewing technology as a boundary object is helpful for understanding how to better promote such unified scientizing experiences for learners. When we recognize practices, tools, and artifacts as boundary objects we can better design them to promote learning (Wenger, 2000). Therefore, pointing to technology as a boundary object for promoting disposition can foster a useful perspective for designing new technologies (of all types) to promote disposition. This work also highlights challenges that remain in understanding how to best design and use technology to promote disposition development. Specifically, it points to the need for understanding ways to effectively connect learners' participation to broader communities and for using learning analytics as a means to alert educators of learners' progress. More work is needed to understand the role of technologies that serve as boundary objects over longer periods of time and how such technologies can be integrated into learning environments to successfully promote disposition.

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