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People, Places, and Pets: Situating STEM Education in Youths' Homes with their Pets

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Abstract: We facilitated a remote educational summer camp for teenage youth, with participants "sheltering in place" at home due to the COVID-19 pandemic. The summer camp was part of an initiative aimed at promoting STEM education for youth through learning about their pets' senses and engaging in a co-design project to enrich aspects of their pets' lives. We describe how situating scientific and design activities within the home and with pets engages participants in ethnomethodological practices such as field work, naturalistic observation, and in situ design that build upon their funds of knowledge. We discuss implications for the designs of learning environments that leverage the benefits of at-home science and design with pets.

Introduction

As part of a larger project (Kelly et al., 2020), we planned to hold a summer camp for teenage youth to engage adolescents and their pets in feminist-oriented science, design, and engineering during the summer of 2020. Due to the COVID-19 pandemic, we were forced to run the entire program with facilitators and participants staying in their homes. We designed the camp to make the most of participants' time at home with their pets and connect empathetic practices to engagement into science and engineering practices (National Research Council, 2012; NGSS Lead States, 2013). We structured the camp to engage participants to learn about their pets' senses and experiences at home, and to engage participants in week-long co-design projects with the goal of enriching their own pets' lives. Drawing inspiration from Hollan and Stornetta's (1992) paper on how researchers and designers should leave behind notions of simply using telecommunication to recreate the experience of "being there," we use this experience created by circumstance to examine aspects of location, timing, and mode in learning environment design that may be useful well beyond the pandemic. We present the design of our remote summer camp, identify several key advantages of this type of learning environment, and summarize implications for the learning sciences community

Camp design

Theoretical and conceptual background

Researchers have taken different approaches to the ways in which homes, classrooms, and other spaces can support learning. Learning environment design in both informal and formal settings tends to aim towards physically co-located and synchronous facilitation when possible, increasingly with CSCL tools to mediate productive interaction, shared inscriptions, and records (Tissenbaum & Slotta, 2019). Exceptions to co-location in formal and informal education programs tend to occur when participants are geographically distributed and cannot travel to be together, and exceptions to synchronous tend to be when time is desired for individual preparation, practice, or reinforcement, as in flipped classrooms (Akçayır & Akçayır, 2018), or when time is desired for reflection and development of products. Connected learning acknowledges that learning happens across spaces and relationships in people's lives (Ito et al., 2013, 2020). Oftentimes, the home is still a proxy of connected learning for further activities that are done in the classroom. In our work, we directly situate the scientific inquiry and discovery in the home. The usual preference for in-class learning over at-home learning limits opportunities for students' home-based funds of knowledge to inform, motivate, and contextualize learning (Moll et al., 1992). Rather than simply recreating the same kinds of in-class experiences with Zoom and other media spaces for collaboration, we aimed to go "beyond being there" and designed situated learning experiences that would take place within the context (including physical affordances and relations with other actors) of youths' homes (Gaver, 1992; Hollan & Stornetta, 1992). "Activity and setting are seen as mutually crafting" (Lave, 1982, p. 6). Situating scientific and engineering problems within youths' homes with their pets establishes students as independent researchers, and more importantly, as experts, as they can draw on their direct experience and prior knowledge of their pets. We aimed to create at-home activities ("homework"), but not in the traditional sense of homework that is done to reinforce or expand upon learning done in the classroom (Carr, 2013), but as ethnomethodological and CSCW-style field work that students do within their homes to inform in situ co-design

projects (Dourish & Button, 1998). Observing organisms in the field through naturalistic observation is an invaluable practice for understanding an animal's behavior in its natural environment by recording its reactions to unmanipulated stimuli (Salkind, 2010). Ethnomethodologically-oriented inquiry and design inform one another. In the case of designing for non-human stakeholders, Animal-Computer Interaction researchers view co-design as a powerful method that gives animals more agency because of its integration of stakeholders into all phases of the design process (Sanders & Stappers, 2008; Hirskyj-Douglas et al., 2017). By establishing students' homes as valuable research and design sites, we counter the privileging of classrooms separated from homes as sites for learning; acknowledging students, and their pets, as equally valuable co-creators of knowledge using the physical places where they live, together.

Overview

We designed the camp to draw on the advantages of being at home, particularly the advantage of participants spending time with their pets while performing ethnomethodological activities and creating co-design projects. Placing science and engineering work in the context of the home situates participants' scientific inquiry and investigation within their pets' natural environment, amid all the normal stimuli and routines they encounter. We conjecture this learning environment design enables participants to draw upon funds of knowledge from their homes and relationships with their pets. We designed the first week of camp for participants to engage in scientific inquiry and investigation of their pets' senses, as well as to observe their pets' behaviors interacting with different stimuli. We designed the second week of camp for each participant to co-design a project with their pet to enrich some aspect of their pet's life. We distributed assignments and resources via Google Classroom and met weekday mornings as a group for one hour over Zoom. We designed a mix of asynchronous at-home activities, and synchronous activities to do as a group in our Zoom sessions.

Recruitment

We recruited middle and high school aged youths through a STEM mailing list of people who previously participated in a science or engineering summer camp. We used a flyer that described the virtual camp activities, including estimates of how participants would spend their time. The participation criteria were that participants were between the ages of 13–18, had at least one pet dog or cat at home, and had internet and computer access. 13 youths, 9 dogs, and 5 cats participated in our study with 11 youths completing the camp (see Figure 1).

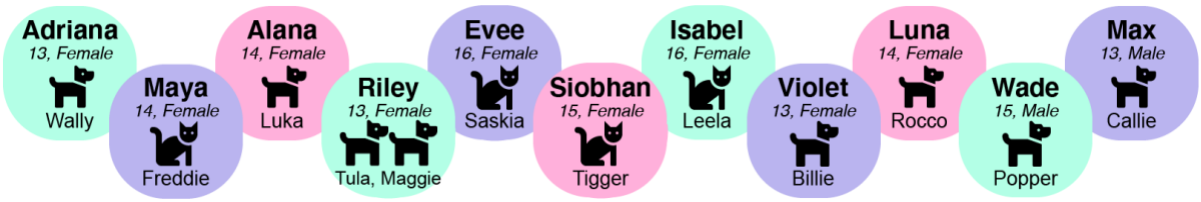

Figure 1. Participants' pseudonyms, ages, genders, and pet information.

Key asynchronous and synchronous activities

We shipped materials to participants to support their at-home activities and co-design projects. Each participant had a Pet Blog, which was a personalized Google Slides presentation where participants documented their at-home activities and co-design project. We orchestrated synchronous group share-outs over Zoom where participants reported their activity and project progress with the group. We also conducted group discussions (in full groups and smaller breakout groups) that helped participants generate ideas and questions for their later at-home activities. We used Google Docs and Slides, so participants could collaboratively comment on the document in real-time, post questions in the Zoom chat, or speak up verbally if they felt comfortable. For the first at-home activity, participants developed a mock social media profile for their pet and completed an ASPCA feline-ality or canine-ality assessment and reflected on their pet's personality type result (ASPCA 2007a; 2007b). Prior to this study, we developed two Snapchat lenses called DoggyVision and KittyVision (Kelly et al., 2020). These lenses simulate canine and feline visual differences: color perception, visual acuity, and brightness discrimination (Miller & Murphy, 1995). When users enable the lenses, they can see the effects in real-time on their phones' camera feeds and can capture photographs and videos of the scenes they are viewing—enabling participants to see their pets' home environments as they would. The day two activity was an at-home exploration with DoggyVision and KittyVision; participants viewed areas inside and outside of the house that their pets frequent using the lenses and took observational notes. On day three, participants designed an experiment using Doggy- or KittyVision to investigate a question they had about their pet's vision. On day four, participants observed their pet's reactions to

different sound stimuli, and designed a wearable paper model of their pet's pinnae (outer ears) and made observations about their differences in their hearing and their pet's and wrote about sounds that stimulate or frighten their pets. Our day five activity (the last day of week one) was inspired by behavior tracking techniques from the animal sciences (Lehner, 1992). Participants observed their pets throughout the day and over the weekend and used their logs to make claims about their pet's emotional and mental states and the contributing environmental factors. Participants also used these techniques throughout week two for testing and evaluating their co-design projects with their pets. The week two activities guided participants through the process of creating co-design projects, including designing and building initial prototypes, and evaluating and iterating on their projects each day at home. At the beginning of week two (day six), each student wrote a proposal for a co-design project and developed a design persona ("pet-sona") to represent their pet as a co-design stakeholder (Hirskyj-Douglas et al., 2017). On days seven, eight, and nine (the penultimate day) participants provided daily project updates in class and in their Pet Blogs that included their project revisions, the methods they used to evaluate their project, and the results of their testing. Their results included successful aspects of their project and revision plans to address the unsuccessful aspects of their projects. On the penultimate day of camp, participants created a final video project presentation about their co-design projects. Participants presented their videos on the last day, while facilitators and campers asked questions.

Data collection and analysis

We saved participants' at-home Pet Blog work, in-class collaborative work, and recordings of all Zoom interactions. Additionally, we recorded exit-interviews with nine participants. We content logged and partially transcribed participants' exit-interviews, focusing on their experiences engaging in science and engineering at home. We performed a thematic analysis on the data, focusing on themes pertaining to participants' engagement in their at-home activities with their pets, and on how being at home shaped their practices and experiences regarding scientific experimentation and observation. As part of a larger analysis, we described in detail the links between science and engineering practices (NRC, 2012; NGSS Lead States, 2013), care, and empathy in participants' co-design work with pets. That work informed the analysis in this paper, where the emphasis is on how being situated in the home, with their pets, influenced the experience of doing science and engineering using the framework described in the Theoretical and Conceptual Background.

Findings and discussion

At-home activities as field work drawing upon funds of knowledge

The asynchronous camp activities promoted participants' enactment of ethnomethodological field work with their pets and in their homes. Situating this work in participants' homes with their pets enabled them to perform naturalistic observation, and to build on their funds of knowledge regarding their pets. One participant, Violet, reflected on the benefit of being able to participate at home with her dog from Texas (~950 miles distant from the facilitators' locations), saying, "this is [Billie's] environment and she knows it much better…her environment here is so much more different here than in Colorado." Violet's statement demonstrates the importance of place in this learning environment, particularly how participating somewhere other than their home would alter her and Billie's experiences of the camp.

Participants incorporated their and their pets' home environments and normal routines into their scientific work. For example, during the behavior tracking at-home assignment, participants logged their pets' behaviors and made arguments for what environmental stimuli in or outside the home were influencing these behaviors. Participants used this evidence, and drew on their funds of knowledge, to argue what their pets' emotional and mental states were. For example, Adriana's family had a visitor come over with a new puppy and she tracked Wally's interactions and behaviors around the puppy, writing observations such as, "If [the puppy] did something that Wally didn't like, he would growl at her. It was a low growl coming from the back of his throat." Based on Adriana's observations of Wally's growling, and engaging in behaviors such as "stalking her" and "try[ing] to stand up taller and appear bigger," she argued Wally was feeling territorial and therefore trying to assert his dominance over the puppy. In addition, when Adriana was evaluating Wally's interaction with her design project (a comfortable napping crate for Wally), she noted similar growling behavior. Adriana knew to associate growling with territorial behavior, therefore, Adriana noted this as a sign that Wally liked the napping crate. She wrote, "he was protective of the crate, and was thinking of it as his." The ability to observe Wally at home enabled her to see these territorial behaviors; had she and Wally participated in a different location Wally would not display the same ownership and comfort of the space.

In addition to the importance of *place*, the behavior tracking assignment displayed the importance of *relationships*; particularly, the value of participants' intimate knowledge of their pets. Adriana had knowledge of

Wally's sleeping preferences, saying "[Wally] loves resting in tight spaces...When he's napping, he'll often do it behind the dinner table, or up against the wall or couch." This knowledge of Wally's sleeping preferences is what led Adriana to choose to design a new, comfortable sleeping space for him for her project. This use of prior knowledge was also prevalent in one of Riley's behavior logs. Riley noted, unlike other dogs, Tula does not wag her tail when she is excited. She wrote, "[Tula] never really straightens her tail so this is just in its normal position...she is enjoying it too much to think about wagging it." Riley's assessment of Tula's mood required intimate knowledge of her behaviors. Whereas an outside researcher or other camper may have perceived Tula's lack of tail-wagging as a sign of discontent, Riley utilized her prior knowledge and relationship with Tula to explain why the opposite was true. To demonstrate the importance of participants' funds of knowledge, we offer a contrasting example; one participant, Maya, adopted her kitten Freddie only an hour before the camp started. Therefore, she lacked the prior knowledge about her pet that develops over time in a relationship. Maya could only perform on-the-spot naturalistic observation, which was also difficult because Freddie was nervous about his new home and tended to hide when she wanted to interact. In reference to this problem, Isabel said "[The feline-ality test] would be difficult for new animals because these animals may not have begun to form unique behaviors and figured out how they handle the world…[Leela] has become a little lazier and less social as she's aged."

Figure 2. Alana's photograph of Luka's ear, a sketch, and her wearing the paper model she designed.

Situating the camp at home was beneficial towards participants' understanding how their pets' senses of sight and sound operated in their natural environments. Participants' use of DoggyVision and KittyVision in and near their homes allowed them to view their pets' natural environments with their simulated color perception firsthand. During Alana's initial explorations with DoggyVision in her home, she took a photograph of a view outside a window that her dog Luka often stares out. In her photo caption, Alana wrote, "this is the view out of a window that [Luka] likes to sit by. The colors are a lot less brilliant and the red flowers across the street blend in with the grass." Not only was Alana building a model of dogs' color perception, she was also viewing the world from her dog's day-to-day perspective—something impossible to do in a school classroom or at a centralized camp location. During the hearing activity, participants observed their pets' reactions to different sound sources and stimuli in and around their homes, as well as recalling prior knowledge of their pets. Alana wrote, "Whenever someone knocks on the door, [Luka's] head shoots up and he becomes very alert." Some participants made note of sounds related to feeding time, Isabel wrote, "We know that [Leela] knows the sound of her food cans opening, as she always runs when she hears it. We also see her react to my dad calling them to dinner." These observations required no manipulation of their pets' environments, and heavily relied on their prior knowledge. Participants' ability to work on the hearing assignment at home also enabled them to record up-close observations of their pets' ears and create detailed sketches of their appearance. This allowed them to design their paper models to more closely resemble the shape of their pets' unique ears, as opposed to a generic dog or cat model (see Figure 2).

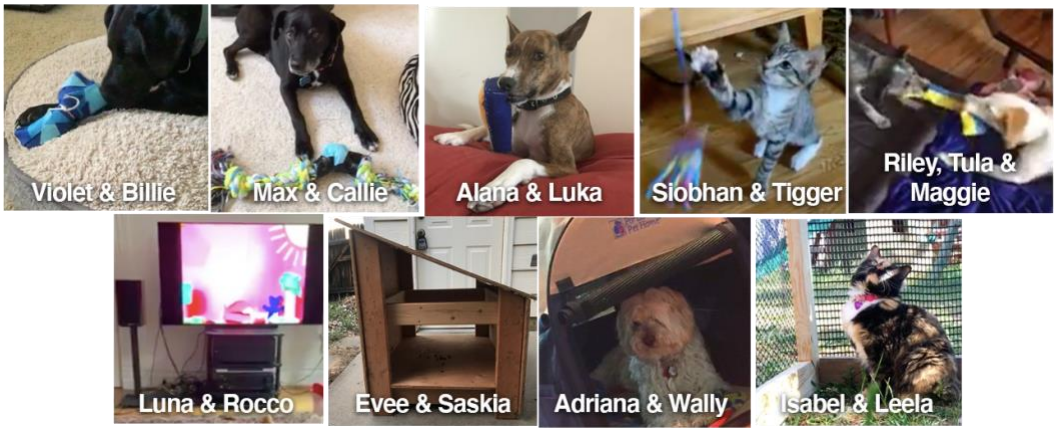

Figure 3. Participants' final co-design projects in use by their pets.

The ability for participants to engage in their experimental and observational activities with their pets at home enabled them to enact ethnomethodological practices and understand their pets' behaviors and senses in their natural environments (Dourish & Button, 1998). In addition, working from home allowed them to build on their funds of knowledge they have from their relationships and cohabitation with their pets. These practices helped participants produce more authentic data about their pets for them to develop hypotheses and to use in their co-design projects. Because each student's co-design project focused on improving their pet's quality of life, students' funds of knowledge helped provide empathetic motives for their design interventions. Students' co-design projects fell into two major categories: 1) new toys that were tailored to their pets' specific wants and needs and 2) spaces or environments that would make their pets feel comfortable and safe (see Figure 3).

In situ co-designing with pets

The ability for participants to work on their co-design projects from home allowed them to create projects that integrated seamlessly into their homes, and enabled participants to engage their pets in all stages of the design process, whereas participating in a classroom or camp location outside of their homes would create disjoint stages of iteration and evaluation. All phases of designing were situated in the context of theirs and their pets' natural lives: understanding stakeholder requirements (which we highlighted in the last section through examples of participants' at-home field work and observations), prototyping, evaluating, and revising.

As an initial stage of their co-design projects, participants developed design personas ("pet-sonas") for their co-design projects. Luna wanted to design a TV show for Rocco and wrote down her observations of how Rocco typically interacts with the TV, "Rocco loves to watch the tv when my family is sitting near it watching a show. He enjoys the sounds and visuals on the tv screen...when there is a loud or interesting sound his ears will perk up and he may run over to the screen." Luna's description captures both how Rocco interacts with the television, and also how his interest in the television is tied to spending time with the rest of the family. Isabel wanted to build an extension to her cat's current outdoor enclosure for her project, so she wrote about how Leela typically interacts with the current enclosure, "Leela mainly spends her time on the ground, eating grass, but she also enjoys the vertical shelves, which gives her a vantage point...she often claws at the fencing and clearly wants to be able to move around freely" (see Figure 4).

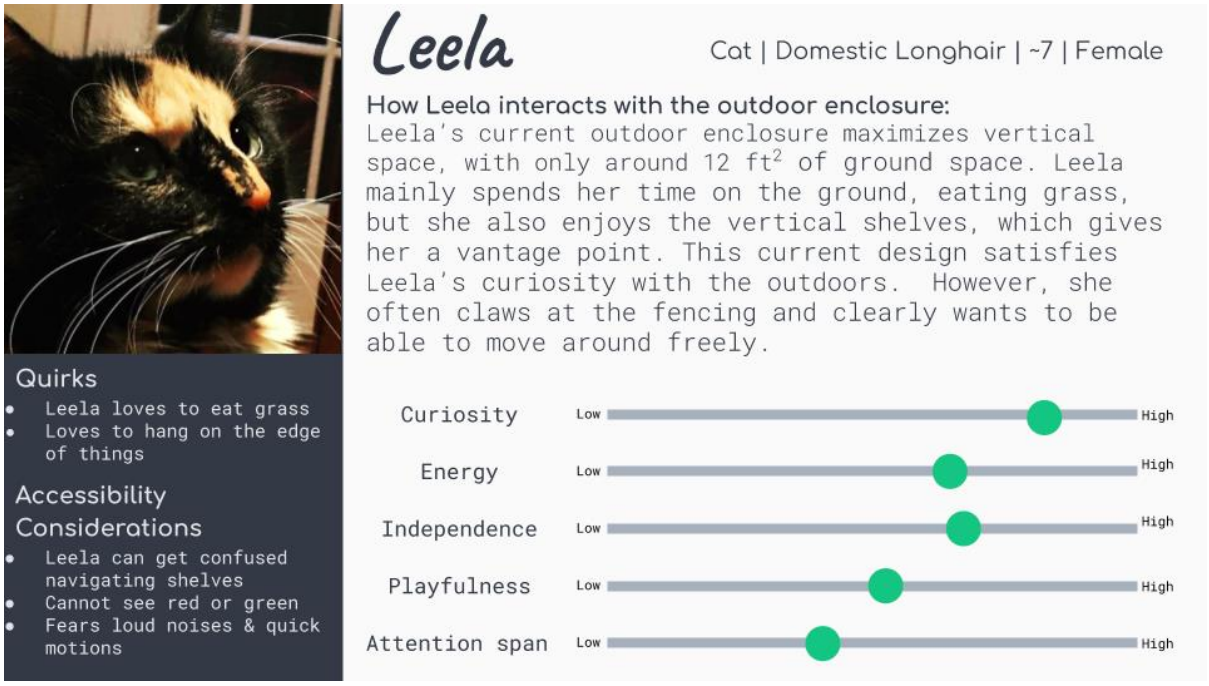

Figure 4. Isabel created this "cat-sona" to represent her cat Leela.

Conducting experiments and testing their projects at home with DoggyVision and KittyVision allowed participants to determine what colors were visually accessible for their pets in their natural environments, and to eventually evaluate what their prototypes looked like in their own homes. Figure 5 shows Violet's experiment she conducted with Billie to investigate whether she had a particular color preference in her toys. Being at home gave

Violet access to Billie's toys, as well as the ability to experiment in situ with Billie in an unmanipulated environment familiar to both dog and human. In her tests, Violet played with Billie in her normal habitat (the living room), and Violet collected DoggyVision photos to see how Billie's toys looked on their carpet. Based on her tests, Violet ascertained that bright blue was the most engaging to Billie, which led her to design a toy prototype that included varying shades of blue. Similarly, Riley used DoggyVision to observe how her toy prototype looked on different surfaces (grass, concrete, wood floor) to test if the colors would be visually accessible to her dogs. She wanted to compare the appearance of the new prototype against one of her dogs' old ratty toys to evaluate whether or not there was a visual improvement. Riley collected side-by-side photographic evidence of the old toy and new toy in three different locations: the backyard, the back deck, and a room in the house (see Figure 6).

Figure 5. Violet's documentation of her color preference test with Billie

Figure 6. Riley's side-by-side DoggyVision photos of her dogs' old toy and her new toy prototype.

Situating the co-design projects at home required participants to develop a sense of their pets' schedules and behaviors throughout the day. Many participants had to adapt their testing methods depending on the time of day. For example, Siobhan tried to keep her testing times consistent because Tigger was more active in the evenings and "his energy level also changed how he reacted to the toy." Similarly, Evee was worried that testing her prototype at night would cause her to have to force Saskia to interact with it because of the rushed timeline. To address this, she said "I made my changes and set it up in the late morning so that [Saskia] would have all day to explore it and get used to it if she wanted to." Sometimes, the pets were in control of when tests took place. One time, Riley was in a Zoom session and Maggie wanted to play with her and the toy prototype, "While I was on a zoom meeting she was chewing on the toy for a relatively long time. I think she liked the crinkling of the plastic and the smell of the treats and the sound of the rattle when it rolled." This ability for participants to adapt to their pets' needs and routines allowed for impromptu discovery and is a valuable skill for performing in-situ co-design work. In addition, participants who designed toys for their project were able to engage their pets in frequent "play tests" inside and outside of their homes, which situated the process of design and evaluation in a mutually enjoyable activity that established relationships and location as a valuable part of their design processes.

Another advantage of participants working from home was their ability to use at-home resources, and household materials relevant to their personal hobbies and interests. Although we supplied each participant with a box of supplies, all participants used at least one item from their own home for their project. In addition, participants explicitly designed their projects to be a part of the home. Isabel's co-design project was to extend her cat's outdoor enclosure which was attached to the house. Isabel and her cat, Leela, live in a small mountain community where outdoor cats can fall victim to larger predators. Isabel wrote, "[Leela] really likes going outside but it's not really safe for her to do here." Based on her prior knowledge and observations of her cat, she identified Leela wanted more space in her enclosure, saying, "she often claws at the fencing and clearly wants to move around more freely." Isabel's project involved several large pieces of plywood and power tools, which would have been cumbersome or even impossible to transport back and forth between home and school. Because

participants worked on the entirety of their projects at home, they did not need to transport their project materials. In addition, participants could always test their projects in situ because of the constant access to their pets. For example, when Isabel finished sizing her initial extension, she wanted to make sure it accommodated Leela before the next step of putting it all together, "In order to test the revisions to my prototype, I laid out the materials for the extension outside...I will let Leela stand in the structure tomorrow, to ensure that she can fit comfortably" (see Figure 7). Prior to constructing the extension, Isabel built a prototype model using craft materials at home (see Figure 7), saying the experience "helped me realize how to use things in my house." To bring her prototype into fruition, Isabel's father supported her interest and drove her to the hardware store several times to buy materials, which was about an hour and a half round trip drive. Isabel had experience with woodworking at home and from a high school class, saying she "did as much of [the project] as possible on my own," but that her father taught her to use their saw and helped her drill, so she would not damage the house. Isabel's project shows how personal interests, family support, location, and funds of knowledge can connect to an at home co-design project with a pet. Isabel was not the only person whose project connected to a hobby; Riley described herself as being good at sewing and applied this skill to her project creation, "I will sew up my toy with a sewing machine but hand stitch on the smaller sections. I am a good sewer and like to sew clothing and other things in my free time." Riley's statement demonstrates her integration of a personal interest (sewing) into her design project.

Figure 7. Isabel's model prototypes (A and B), the materials Isabel laid out to test the enclosure size (C), and Leela enjoying the final enclosure (D).

Situating participants' co-design projects at home allowed for a cohesive process of design iteration and evaluation and enabled participants to perform authentic design interventions. Participants created projects specifically designed for their homes and pets, and even integrated their personal hobbies and interests to their projects. Participants developed adaptable testing procedures that worked around their pets' schedules and allowed for spontaneous discovery.

Conclusion

In contrast to Ann Brown's (1992) groundbreaking design experiments in the early days of the learning sciences which were radical in situating what used to be called "educational psychology" in the "blooming, buzzing confusion" of classrooms, we explored what could be gained by working in the blooming, buzzing context of learners' homes during a pandemic that made gathering in in-person groups for summer camp impossible. Facilitating a remote STEM summer camp enabled us to situate participants' scientific, design, and engineering activities within their own homes, building on their relationships with their pets and their funds of knowledge while participating in structured learning activities with a distributed group. Participants conducted activities with their pets at home; allowing them to engage in ethnomethodological fieldwork practices such as naturalistic observation and in situ design and draw on prior knowledge they have about their pets. The ability for participants to work in their free time, allowed them to test with their pets at optimal times, which involved learning to adapt to their pets' behaviors and schedules. This flexibility in designing in situ allowed for more authentic data for their co-design project iterations. Even though we applied an asynchronous, distributed learning model out of necessity, we believe this type of learning environment should always include some level of asynchronous at-home work due to the advantages we have highlighted. One downside of remote participation several participants mentioned was the lack of connection with other campers. To address this, future iterations could seek to enhance social interaction and community-building among campers, through additional in-person or online activities that foster interpersonal interaction and collaboration, while still situating the core experimental and observational work within participants' homes. Our experience points to a lesson for designing the location of learning experiences: changing the focus to what ethnomethodological fieldwork and design work makes sense to do remotely as asynchronous "homework" (in this case at home where learners lived with their pets), and what social

and interactional work makes sense to do synchronously, with various inscriptional tools used to support either remote or face-to-face discussion.

References

Akçayır, G., & Akçayır, M. (2018). The flipped classroom: A review of its advantages and challenges. Computers & Education, 126, 334-345. Elsevier Ltd.

ASPCA. (2007b). Meet Your Match® Feline-ality™ Training Manual. American Society for the Prevention of Cruelty to Animals [PDF file]. New York, NY, USA. Retrieved from https://www.aspcapro.org/sites/default/files/Feline-ality%20Guide_PRO.pdf

ASPCA. (2007a). Meet Your Match® Canine-ality™ and Puppy-ality™ Training Manual. American Society for the Prevention of Cruelty to Animals [PDF file]. New York, NY, USA. Retrieved from https://www.aspcapro.org/sites/default/files/aspca-canine-ality-guide-2015.pdf

Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. The Journal of the Learning Sciences, 2(2), 141–178.

Carr, N. S. (2013). Increasing the Effectiveness of Homework for All Learners in the Inclusive Classroom. School Community Journal, 23(1), 169-182.

Gaver, W. W. (1992, December). The affordances of media spaces for collaboration. In Proceedings of the 1992 ACM conference on Computer-supported cooperative work (pp. 17-24).

Hirskyj-Douglas, I., Read, J. C., & Horton, M. (2017). Animal Personas: Representing Dog Stakeholders in Interaction Design. In British Human-Computer Interaction proceedings, 3-6 July, 2017, Sunderland, UK. ACM, New York, NY, USA. https://doi.org/10.14236/ewic/HCI2017.37

Hollan, J., & Stornetta, S. (1992). Beyond being there. Conference on Human Factors in Computing Systems - Proceedings, 119–125. https://doi.org/10.1145/142750.142769

Ito, M., Gutiérrez, K., Livingstone, S., Penuel, B., Rhodes, J., Salen, K., Schor, J. Sefton-Green, J., & Watkins, S. C. (2013). Connected learning: An agenda for research and design. Digital Media and Learning Research Hub.

Ito, M., et al. (2020). The Connected Learning Research Network: Reflections on a decade of engaged scholarship. Connected Learning Alliance.

Kelly, A., Chang, C., Hill, C. N., West, M., Yoder, M., Polman, J. L., Kane, S. K., Eisenberg, M. & Shapiro, R. B. (2020). "Our Dog Probably Thinks Christmas is Really Boring": Re-mediating Science Education for Feminist-Inspired Inquiry. In M. Gresalfi & Seidel Horn, I. (Eds.), *The Interdisciplinarity of the Learning Sciences, 14th International Conference of the Learning Sciences (ICLS), Volume 2* (pp. 935-942). International Society of the Learning Sciences.

Lave, J. (1982). The Mature Practice of Arithmetic Problem Solving in the Daily Lives of Americans. Final Report.

Lehner, P. N. (1992). Sampling methods in behavior research. Poult Sci. Apr;71(4):643-9. https://doi.org/10.3382/ps.0710643

Miller, P .E. & Murphy, C. J. (1995). Vision in Dogs. Journal of the American Veterinary Medical Association, 207(12), 1623–1634.

National Research Council. (2012). A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. The National Academies Press.

NGSS Lead States. (2013). Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

Salkind, N. J. (2010). Encyclopedia of research design (Vols. 1-0). Thousand Oaks, CA: SAGE Publications, Inc. https://doi.org/10.4135/9781412961288

Sanders, E. B.-N. & Stappers, P. J. (2008). Co-creation and the new landscapes of design, CoDesign, 4:1, 5-18, https://doi.org/10.1080/15710880701875068

Tissenbaum, M., & Slotta, J. D. (2019). Developing a smart classroom infrastructure to support real-time student collaboration and inquiry: A 4-year design study. Instructional Science, 47(4), 423-462.

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