“Our Dog Probably Thinks Christmas Is Really Boring”: Re-mediating Science Education for Feminist-inspired Inquiry

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Abstract: Feminist science approaches recognize the value of integrating empathy, closeness, subjectivity, and caring into scientific sensemaking. These approaches reject the notion that scientists must be objective and dispassionate, and expand the possibilities of what is considered valuable scientific knowledge. One avenue for engaging people in empathetically driven scientific inquiry is through learning activities about how our pets experience the world. In this study, we developed an augmented reality device we called *DoggyVision* that lets people see the world similar to dogs' vision. We designed a scavenger-hunt for families where they explored indoor and outdoor environments with DoggyVision, collected data firsthand, and drew conclusions about the differences between how humans and dogs see the world. In this paper, we illustrate how our DoggyVision workshop re-mediated scientific inquiry and supported the integration of feminist practices into scientific sensemaking.

Keywords: Augmented reality, scientific inquiry, perspective-taking, families, feminism

Introduction

Feminist critiques reject the notion that scientific sensemaking requires rationality, formality, and objectivity and promote the values of improvisation, engagement, and subjectivity (Warren, et al., 2001). These perspectives challenge Western scientific methodologies and instead value closeness between the researcher and the population they are studying, and reject complete objectivity. Reconstructing science education to respond to feminist and indigenous critiques of science (and science education) must contend with questions like: What are the phenomena to be investigated? What processes for inquiry will be used? How will students' learning be mediated by material artifacts, including new educational technologies?

In this study, we investigate how augmented reality technologies can remediate phenomenological exploration of the world through the eyes of another species. This investigation is intended as a springboard into research on how sensory augmentation can support science and science education that are aligned with feminist ideas for reconstituting science, emphasizing closeness, caring, and empathy, rather than objective distance from what is studied. By focusing on human-pet relationships, we aim to leverage the already existing affection and empathy that people feel for their pets to promote scientific questioning and investigation. In this paper, we present a pilot study of remediating human vision with augmented reality to support animal-like perspective-taking in the context of a whole-family, inquiry activity. We show how this remediation can support inter-species perspective taking that is well-aligned with feminist theories of science.

Background

Feminist critiques of science and science education

Feminist critiques of science, informed by indigenous and other critical approaches, challenge inequitable and oppressive structures that dictate who participates in science, what kinds of knowledge science produces, and the processes of scientific knowledge production (Cancian, 1992; Medin & Bang, 2014). These critiques question the highly-regarded positivist values of Western science that emphasize objectivity and control (Cancian, 1992), arguing that they reaffirm colonizing attitudes that reify oppressor-oppressed structures in education. Oppressive education prevents non-privileged people from being co-creators of knowledge, instead treating them as passive objects that need to assimilate to the beliefs and values of the oppressor (Freire, 2000; Smith, 1999). Decolonizing education requires deviating from the structures that reinforce privileged production of knowledge by creating more equitable relationships between learner and educator, and developing respectful and ethical research practices that acknowledge the lives and perspectives of marginalized groups (Smith, 1999).

Keller argues we can challenge the male biases of science without hindering progress towards scientific truth (Keller, 1982). Feminist science perspectives argue we do not need to discard emotion to make rational progress, and that scientists can value closeness over distance, subjectivity over objectivity, empathy over dispassion, and caring over control (Warren, et al., 2001).

Perspective-taking as a catalyst for feminist scientific inquiry

The public stereotypes scientists as cold and distant, branding the discipline as one lacking enjoyment and love (Losh, 2010). These stereotypes support a perceived rift between the so-called "hard" skills of experimental design, data collection, quantitative analysis, and argumentation (Duschl & Bybee, 2014; O'Neill & Polman, 2004), and the so-called "soft" skills such as care, empathy, affection, and collaboration. This false dichotomy suggests that to scientifically understand a phenomenon, it must be done through a purely objective account through distancing oneself from the object of study. However, Nobel Laureate Barbara McClintock spoke about developing relationships with the organisms she studied, "You need to know those plants well enough…I know them intimately, and I find it a great pleasure to know them" (McClintock, as quoted in Keller, 1983).

Rosser suggests research-based teaching techniques can attract and retain women in science; among these techniques are using "more interactive methods, thereby shortening the distance between the observer and the object studied" as well as reducing methodologies that require harsh treatment of animals (Rosser, 1997). Rosser's techniques highlight a more empathetic and emotionally-attentive approach to science. Cancian describes a similar participatory approach, favoring "methods that give research subjects more power" and reduce the separation between subject and researcher (Cancian, 1992). Jaber and Hammer (2016) likewise emphasize the importance of teachers recognizing the feelings invoked in their students who are doing science.

When Howes (2002) conducted interviews with children to examine their conceptions of male and female abilities to be successful in science professions, she found that girls viewed emotion and empathy as precluding being a good scientist. However, despite these perceptions, sciences related to animals and animal behavior, such as primatology and animal science, have been suggested to be feminist sciences (Fedigan, 1997), and arguments for feminist rights raise many issues similar to animal rights (Birke, 1994). We suggest that the use of perspective-taking, such as that used by McClintock, can be a way to engage youth in scientific exploration and inquiry and demonstrate to them the validity of empathy skills in scientific careers.

A relational epistemology informed by perspective-taking, empathy, and connection to the natural world is not only reflective of contemporary philosophy of science; it directly supports more effective science education driven by inquiry (Loh, et al., 2001; Anderson, 2002; Krajcik, et al., 1998; NGSS Lead States, 2013). The *Framework for K-12 Science Education* (National Research Council, 2012), which informed the *Next Generation Science Standards* (NGSS Lead States, 2013), highlights key scientific practices which all benefit from a relational inquiry stance informed by perspective-taking and systems thinking: asking questions and defining problems, planning and carrying out investigations, analyzing and interpreting data, constructing explanations and designing solutions, engaging in argument from evidence, and obtaining, evaluating, and communicating information. Inquiry can look like many different things, and may not produce immediate "results" in the form of answers, as some students and teachers might expect (Loh, et al., 2001). A product of inquiry can be new questions and curiosities for investigation about phenomena at hand.

Augmented reality, perspective-taking, and science education

Augmented Reality (AR) involves the overlaying of digital graphical objects onto real world environments. AR has become more prevalent in educational settings and is more accessible than ever due to its ability to run on mobile phones (Nincarean, 2013). Some of AR's educational affordances include motivating and engaging students to explore the world around them, providing opportunities to explore settings that would otherwise be impossible to experience, and enhancing collaboration and creativity (Yuen, Yaoyuneyong, & Johnson, 2011).

AR has the benefit of providing real-time augmented representations of the physical world, offering the affordance to provide people the ability to collect data from a firsthand account, fostering education experiences that are embodied, hands-on, and interactive (Bower & Sturman, 2015). This affordance is similar to that of wearable technologies, and in some instances practitioners have applied AR and wearable technology in educational initiatives that focus on "quantifying the self"; in other words, projects where students collect real-time information about their bodies or day-to-day activities (Lee, 2018). While these technologies can support learning about oneself, these technologies can also support learning beyond the self by giving wearers new or enhanced sensory experiences (Shull & Damian, 2015). In particular, enhancing our visual senses is a task well-suited for AR. AR has the affordance of providing augmented visual experiences, whereas other types of wearables would be more suited to provide senses that involve physical stimulus.

Providing humans with augmented sensory experiences supports perspective-taking of other beings' experiences (Eisenberg, 2017). We argue that providing empathetic perspective-taking opportunities can promote engagement and closeness in scientific sense-making, which are key tenets of feminist science.

Designing for phenomenological inquiry into pet perception

People often view pets as companions and loved members of the family (Bilger, 2003; Bucks, 1903). People's desires to understand how their pets are feeling can motivate them to scientifically investigate differences in their perception and daily lives. Thompson and Gullone (2003, p. 7) say "...by developing a strong bond with an animal, children are likely to demonstrate increased levels of animal-directed empathy." Poresky (1990) found that children who had strong bonds with their pets had higher empathy scores than young children without a pet. By invoking children's (and their parents') empathy for their pets, they may be more inclined to ask deeper scientific questions about animals' experiences in the world. Since 68% of households in the United States own pets, with 60.2 million households owning dogs (Insurance Information Institute, 2018), learning experiences that leverage pet owners' connections with their pets could create a context for feminist, perspective-taking rich scientific inquiry within families.

Pets can be companions for children's play, including play where children progress from ego-centricity toward empathy and perspective-taking (Kidd & Kidd, 1985). Marvin et. al (1976) distinguished between two types of perspective-taking: *perceptual* perspective-taking which involves making inferences about someone else's sensory experiences such as their visual and auditory perceptions, and *conceptual* perspective-taking which concerns considering someone else's emotional and internal experiences such as their thoughts and desires. Perspective-taking is an empathetic practice. We conjecture that people's empathy for their pets can cultivate animal perspective-taking and encourage scientific inquiry around how their pets experience the world.

It can be difficult to understand what animals are feeling without projecting our own experiences onto them. Our lives and experiences differ in how we think, see, smell, and otherwise exist in the world. In attempting to imagine what it is like to be a bat, Nagel encountered the mind-body problem, saying, "...I want to know what it is like for a bat to be a bat. Yet if I try to imagine this, I am restricted to the resources of my own mind" (Nagel, 1974, p. 439). AR and wearable technologies can assist in making these connections, addressing the "body" aspect of the problem, and can help people to develop their own observations and questions about animal perception and can support deeper understanding of inter-species' biologically-based differences in perception, which can in turn spark curiosities about other species' experiences in the world.

To explore the potential of AR technologies to support a feminist-inspired perceptually-focused approach to science education, we (1) designed a mobile augmented reality application that enables humans to see color from a dog's perspective and (2) conducted a workshop for families around using these sensory perception technologies to take on the perspectives of their pets within an inquiry activity.

DoggyVision application design

In order to understand how sensory augmentation technologies can facilitate scientific inquiry and empathy related to animals, we developed an augmented reality application called DoggyVision that modifies a mobile phone's video feed in realtime to show users what their environment looks like when seen through a dog's eyes.

DoggyVision achieves this visual effect by removing all red and green hues from the live video camera feed displayed on the phone, leaving behind only the colors that dogs can see. Dogs' eyes contain fewer cone cells and their range of color vision is a mix of blues, grays, yellows, and browns as opposed to the red, green, and blue cone cells that most humans have that allow us to see a wider range of colors (Miller & Murphy, 1995). Therefore, images viewed in DoggyVision have a much smaller range of colors than can be seen by a typical human eye; the resulting visual effect is similar to that in humans who have dichromatic red-green color blindness, contrary to the common misconception that dogs can only see the world in black and white. Figure 1 depicts a side-by-side photo of an image taken in full color mode and in DoggyVision. The left photo has "human vision" coloration and shows birds of varying colors. The photo on the right, the dichromatic "doggy vision" version, depicts fewer colors, causing the birds to be practically indistinguishable from one another.

When users tap the screen, the app saves two photos to the phone: one *filtered* photo in the altered colors of DoggyVision and another *unfiltered* photo in unaltered "normal" colors, allowing the user to observe the photographs side-by-side at a later time.

Methods

Workshop design

We conducted a 2-hour family workshop at a museum on the campus of a large public university in the western United States. We designed this workshop for whole families rather than children alone because animal care is often a family endeavor and we wanted our study to capture families' perspectives about their pets.

We began the workshop with introductions where we all shared our names, what kinds of pets we have, and something interesting about our pet. We then introduced the photo scavenger hunt activity. We provided each youth participant with an iPhone running DoggyVision, and provided one adult from each family with a list of items to photograph in DoggyVision with space for notes. We asked participants to write notes about their photographs and to look for items beyond those listed on the worksheet. We encouraged families to spend approximately thirty minutes exploring inside the museum and outside around campus. We chose to have children control DoggyVision, and for parents to take notes because we were curious about what things children would find visually interesting and how they would talk about what they were seeing from a non-expert perspective. In addition, by explicitly separating the roles family members had during the scavenger hunt, we hoped to encourage the children and their parents to communicate about what they were seeing, allowing us to more effectively understand the participants' thought processes (much as a think aloud protocol might).

After families returned from the scavenger hunt, we facilitated a group discussion. We wrote discussion prompts on large posters at the front of the room, including: What looks the same and different? What are other animal senses you would like to explore with different technology? Given what you learned, what is something you could imagine making for your pet? We asked participants to write down responses to these prompts, and other questions or thoughts that they wanted to share. In addition, facilitators asked each family to choose three sets of photos from their scavenger hunt that they wanted to print. We printed both the dog and human versions of each selected photo on sticky-backed photo paper. Participants placed their printed photos side-by-side on posters in the front of the room and wrote descriptions of why they chose those particular photos. Although participants captured around 100 photos each, we introduced the three-pair constraint to see which photographs stood out to them as especially interesting, a selection process we hoped would lead to a richer discussion about the phenomenon of dog vision and the scavenger hunt experience.

Recruitment

We recruited families through the museum's email newsletter. An online sign-up form requested information from interested families about their family size and what kinds of pets they have. We prioritized families who had at least one pet dog at home because the workshop centered around dog perception and we wanted families to be able to draw on their personal experiences. A total of five families participated in the workshop, ranging in size from 2 to 4 people, with a total of 14 participants. The youth participants ranged in age from 8 to 13, and the adult participant age range was from 44 to 53. The Dixon family was June (mother, 47), Paul (father, 46), Liam (son, 8), and Keira (daughter, 11). The Lewis family was Siobhan (mother, 44), Bryan (father, 45), and Lisa (daughter, 13). The Pantera family contained Marcela (mother, 46) and Jessica (daughter, 13). The Thomas family was Jamie (mother, 53), Jack (father, 46), and Kyle (son, 12). The Whalen family was Emily (mother, 46) and Taylor (son, unknown age). All human and animal names used in this paper are pseudonyms.

Data collection

We captured audio and video recordings during the workshop introduction, the DoggyVision scavenger hunt, and the post-scavenger hunt activities and conversations. In addition, we collected all of the photographs taken by each youth participant using DoggyVision during the scavenger hunt and the notes taken by the parents which provided more context to many of the photos taken by the youth participants. We also retained information that each family provided on our pre-participation form which included the size of the family and what type of pet(s) they have. We obtained the ages of each participant as they arrived at the workshop.

Data analysis

We were primarily interested in what participants noticed while exploring with DoggyVision, as well as how participants made sense of the phenomena they noticed. We content logged (Lofland & Lofland, 1995) the audio and video data, and then coded the data to identify participants use of scientific sense-making practices during the activity (see final paragraph of section "Perspective-taking as a catalyst for feminist scientific inquiry"; NGSS Lead States 2013), and for themes related to perspective-taking and empathy.

Findings

Families had insightful conversations about what phenomena they were seeing. The app mediated participants' perceptions of the world in ways that drew attention to objects that look especially different through dogs' eyes.

Families compared the world viewed through their eyes with viewing through DoggyVision. Participants noticed variations in colors and often projected this information on how they believed their pets experience the world.

Noticing what is similar and different in DoggyVision

As families were exploring inside the museum and outside around the campus, they made comparisons between what their environment looks like with and without DoggyVision. Many of their conversations involved producing explicit comparisons of colors between dog vision and human vision (e.g., red looks brown, yellow looks yellow). We saw several ways that the DoggyVision scavenger hunt encouraged families to engage with different scientific practices such as observation and investigation, analysis, and communicating arguments and information. In one episode, the Whalen family notices which colors look similar or different in DoggyVision:

Emily: So does blue still look like blue?

Taylor: Mhm!

Emily: And what about the other car, what's the color of that car?

Taylor: That looks the same...the color is gray.

Emily: And what about the last car, what color is it?

Taylor: Yellow and it looks yellow.

The family is engaging in the scientific practice of *analyzing and interpreting data* while they make observations about what colors look the same to them in DoggyVision and what colors look different to them. We see that the facilitation decision to have the children control the phones leads to their parents *asking questions* about what their surroundings look like in DoggyVision which in turn encourages their children to engage in *communicating information* about their observations.

During the scavenger hunt, Lisa formulated a hypothesis about what purple should look like in DoggyVision using prior knowledge she has from mixing color and from the color differences she has been observing through DoggyVision, "It'll be blue, because if you mix red and purple you get blue...oh, it looks black!" Lisa is engaging in multiple scientific practices: *arguing based on evidence* that a purple car should look blue in DoggyVision based on her prior experiences, *constructing an explanation* by stating that it will look blue because purple is a mix of red and blue and DoggyVision removes all reds, and *obtaining and evaluating* new data from DoggyVision by commenting that the car looks black instead of blue like she assumed.

Figure 1. Participant photo of art in the museum. The right photo is in DoggyVision. The left photo shows more hues than the right.

The Dixon family had multiple conversations wherein they effectively mapped the colors they normally see onto the colors they perceived with DoggyVision. The father, Paul, talks about his daughter's clothing: "Keira's green pants look faded. Shirt looks darker blue. Red is yellow. Purple is blue. Green is gray," but also notices that, "Keira's Chucks [shoes] look the same, black and white." Later they see a multicolored poster outside the museum (shown in Figure 1), and say, "they're all kind of gray, aren't they?" The Dixon family is enacting the scientific practices of *analyzing and interpreting data* and *communicating information*.

Perspective-taking as an exercise in empathy

Multiple families expressed empathy regarding the biologically-based visual experiences of their dogs and speculated on what this means for their pets' lives and how it impacts the way they experience the world. For example, at least two families observed that squirrels tend to blend into their environment when viewed through DoggyVision, stating that dogs would have a hard time seeing squirrels because they appear camouflaged from a dog's perspective. Inside the museum, the Pantera family observed a taxidermal squirrel, and the daughter pondered, "Now I'm wondering why dogs even want to...chase squirrels." Similarly, June and Paul Dixon viewed a real squirrel using DoggyVision outside:

June: I don't know how the dogs see 'em (squirrels), he so blends in with the grass

Paul: Yeah, it's just their other senses. They've got super smell, super hearing, and vision.

Drawing on prior knowledge, Paul speculates that dogs must utilize their other senses when responding to animals that appear camouflaged to them. Paul is engaging in the scientific practices of *asking questions*, *constructing explanations*, and *engaging in argument from evidence* as he explores the new visual world enabled by DoggyVision. Families also speculated about their dogs' emotions. The Whalen family had the following conversation about how their dog Teela must feel about Christmas colors and green and red toys:

Emily: So what do you think Teela thinks about the things that she sees every day?

Taylor: Our dog probably thinks Christmas is really boring.

Emily: What about her toys? Should we make sure to not get her green and red toys from now on?

Taylor begins by interpreting the data he is obtaining through DoggyVision (noting that red and green turn to brown), and then Emily and Taylor together engage in argument from evidence. The argument that Christmas must be "boring" for their dog is deeply rooted in empathy as Taylor feels sad that his dog would not find Christmas as fun and visually special as he does. This kind of empathy wouldn't be as valued in traditional science education; it not only supported argumentation, but the Whalen family transforms this empathy into action when they decide to avoid buying green and red dog toys.

In the following example, the Pantera family reflects on an amusing memory about their friend's dog's inability to find a red toy in the grass:

Marcela: Do you remember playing with that dog with the red ball? It was so hilarious...There was a red ball and they would never get it. It was sad. They were just looking around, it was really sad.

Jessica: He was like where'd it go?!

Marcela Pantera's reflection on this prior experience is an example of her *constructing an explanation* of why their friend's dog was so bad at finding the red ball. She has used evidence collected from her observations in DoggyVision to ascertain that a red ball on green grass would be visually difficult for a dog to distinguish. She even empathizes with her friend's dog, saying that it was "sad" that he could not locate the red ball on the green grass. Additionally, her daughter, Jessica, speaks empathetically from the dog's perspective and says he must have been thinking "Where'd the ball go?"

During the full-group discussion participants had ideas for things to design for their pets. Multiple families mentioned wanting to design special glasses for their dogs, so that their dogs could see colors that most humans see. This indicates a desire for inter-subjectivity and a desire to enhance their dogs' life experiences, and shows participants beginning to engage in practices related to *designing solutions* based on the evidence they collected. Other participant ideas included a device that could allow someone to experience swimming like a fish or flying like a bird, and a device that would allow people to navigate using the Earth's magnetic fields similar to a bird. These ideas are indicative of participants *asking questions and defining problems* about not understanding the biological experiences of other animals, and shows their desire to *plan and carry out investigations* to answer these questions.

Discussion

Closeness over distance, subjectivity over objectivity, empathy over dispassion, and caring over control— these are core tenets of feminist science which our DoggyVision workshop supported during families' scientific sensemaking (Warren, et al., 2001), and which are not commonly present in traditional science education. DoggyVision enabled families to experience the visual perspective of dogs and to use this perspective-taking to consider implications of what this means for dogs' physical experiences and emotions in their day-to-day lives.

As families used DoggyVision, they began engaging in the scientific practices of asking questions, defining problems, constructing explanations, collecting data and engaging in argument from evidence, designing solutions, and to better understand their pets' and other animals' perceptions of the world, utilizing perspective-taking and empathy to guide their inquiry. In their sensemaking, families connected the phenomena they saw to their own pets' experiences, practicing closeness over distance by considering the feelings and emotions of the subjects of study. These empathy-driven curiosities were made apparent through participants observing that squirrels must be difficult for dogs to see and chase and speculating that Christmas must be "boring" because of their dog's inability to differentiate between green and red. These observations and arguments, which demonstrate empathy over dispassion, as well as subjectivity over objectivity, prompted deeper inquiry, both during the scavenger hunt and in the facilitated group discussion that followed.

In thinking about how particular animals experience the world, participants considered items they might design for animals to enhance the quality of their lives, demonstrating their affection for their pets and the approach of valuing caring over control. Take, for example, the suggestion by youth and adult participants to create glasses for dogs so that they could see the colors that most humans see. In this way, we see the participants utilizing perspective-taking to initiate deeper scientific inquiry.

Limitations and future work

The limitations of this work include privileging higher income families who can afford to own pets, particularly expensive pets like dogs. To address this, we are planning future studies that would accommodate a diverse set of families from varying economic backgrounds by focusing on less expensive pets like fish and cats (Marx et al., 1988). In addition, the families we recruited were already engaged in informal science education. This might suggest that these families are more practiced in enacting scientific sensemaking discourses than the overall population. This potential bias might be avoided in the future by pursuing alternate recruitment avenues.

In future workshops, we could support participants in exploring the ideas described in this paper further thorough investigating answers to their emergent questions, and developing designs for their concepts, engaging families further with the scientific practices of *planning and carrying out investigations*, and to see families physically realize their solutions that they had already begun to design during this workshop.

Conclusion

We have shown how curiosity and empathy can motivate scientific inquiry, including inquiry that is well-aligned with feminist perspectives on science. We see that scientific inquiry driven by sensory augmenting technologies can lead to empathetic insight, including identifying experiences that might feel particularly different to humans and dogs. Empathy and scientific inquiry are mutually supportive, and a powerful combination in the domain of science education.

References

Anderson, R. D. (2002). Reforming science teaching: What research says about inquiry. *Journal of Science Teacher Education*, *13*(1), 1–12.

Bilger, B. (2003) The last meow: Annals of veterinary medicine. *The New Yorker*.

Birke, L. (1994). *Feminism, Animals and Science: The Naming of the Shrew*. Open University Press, Bristol, PA.

Bower, M., & Sturman, D. (2015). What are the educational affordances of wearable technologies? *Computers and Education*, *88*, 343–353. https://doi.org/10.1016/j.compedu.2015.07.013

Bucks, W.F. (1903). Cyno-psychoses: children's thoughts, reactions, and feelings toward pet dogs. *Journal of Genetic Psychology*, *10*(4), 459–513.

Cancian, F. M. (1992). *Feminist Science: Methodologies That Challenge Inequality*, 6(4), 623–642.

Duschl, R. A., & Bybee, R. W. (2014). Planning and carrying out investigations: an entry to learning and to teacher professional development around NGSS science and engineering practices. *International Journal of STEM Education*, *1*(12), 1–9. https://doi.org/10.1186/s40594-014-0012-6

Eisenberg, M. (2017). The binding of Fenrir: Children in an emerging age of transhumanist technology. *IDC 2017 - Proceedings of the 2017 ACM Conference on Interaction Design and Children*, 328–333. https://doi.org/10.1145/3078072.3079744

Fedigan, L. M. (1997). Is primatology a feminist science? In L. Hager (Ed.), *Women In Human Evolution* (pp. 56–75).

Haraway, D. (2003). *The companion species manifesto: Dogs, people, and significant otherness*. Chicago, IL: Prickly Paradigm Press.

Howes, E. V. (2002). *Connecting girls and science: Constructivism, feminism, and science education reform*. Teachers College Press, New York.

Insurance Information Institute. (2018). Facts + Statistics: Pet statistics. Retrieved from https://www.iii.org/fact-statistic/facts-statistics-pet-statistics

Jaber, L. Z. & Hammer, D. (2016). Engaging in science: A feeling for the discipline. *Journal of the Learning Sciences*, *25*(2), 156-202, https://doi.org/10.1080/10508406.2015.1088441

Keller, E. F. (1982). Feminism and science. *Journal of Women in Culture and Society*, 7(3), 589–602.
Keller, E. F. (1983). *A feeling for the organism: the life and work of Barbara McClintock*. W.H. Freeman.
Kidd, A. H. & Kidd, R. M. (1985). Children's attitudes toward their pets. *Psychological Reports*, 57(1).
Krajcik, J., Blumenfeld, P. C., Marx, R. W., Bass, K. M., Fredricks, J., & Soloway, E. (1998). Inquiry in project based science classrooms: Initial attempts by middle school students. *Journal of the Learning Sciences*, *7*(3–4), 313–350.
Lee, V. R. (2018). Personal analytics explorations to support youth learning. In R. Z. Zheng (Ed.), *Digital Technologies and Instructional Design for Personalized Learning*. https://doi.org/10.4018/978-1-5225-3940-7
Lofland, J. & Lofland, L. H. (1995). *Analyzing social settings: A guide to qualitative observation and analysis*. Wadsworth.
Loh, B., Reiser, B. J., Radinsky, J., Edelson, D .C. (2001). Developing reflective inquiry practices: A case study of software, the teacher, and students. *Designing for science: Implications from everyday, classroom, and professional settings*. 279-323.
Losh, S. C. (2010). Stereotypes about scientists over time among US adults: 1983 and 2001. *Public Understanding of Science*, *19*(3), 372–382. https://doi.org/10.1177/0963662508098576
Marvin, R. S., Greenberg, M. T., & Mossler, D. G. (1976). The early development of conceptual perspective taking: Distinguishing among multiple perspectives. *Child Development*, *47*(2). 511–514. https://doi.org/10.2307/1128810
Marx, M. B., Stallones, L. B., Garrity, T. F., & Johnson, T. P. (1988). Demographics of pet ownership among US adults 21 to 64 years of age. *Anthrozoös*, *2*(1), 33-37.
Medin, D. L. & Bang, M. (2014). *Who's asking?: Native science, Western science, and science education*. MIT Press.
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.
Nagel, T. (1974). What is it like to be a bat? *The Philosophical Review*, *83*(4), 435–450.
NGSS Lead States. (2013). *Next generation science standards: For states, by states*. The National Academies Press.
Nincarean, D., Alia, M. B., Halim, N. D. A., & Rahman, M. H. A. (2013). Mobile augmented reality: The potential for education. *Procedia - Social and Behavioral Sciences*, 103, 657–664. https://doi.org/10.1016/j.sbspro.2013.10.385
O'Neill, D. K. and Polman, J. L. (2004), Why educate "little scientists?" Examining the potential of Practice-based scientific literacy. *Journal of Research in Science Teach*ing, 41(3), 234-266. https://doi.org/10.1002/tea.20001
Poresky, R. H. (1990). The young children's empathy measure: Reliability, validity and effects of companion animal bonding. *Psychological Reports*, 66, 931–936.
Rosser, S. (1997). Re-Engineering Female Friendly Science. Teachers College Press, New York.
Smith, L. T. (1999). *Decolonizing methodologies: Research and indigenous peoples*. Zed Books; University of Otago Press/St. Martin's Press.
Shull, P. B., & Damian, D. D. (2015). Haptic wearables as sensory replacement, sensory augmentation and trainer - A review. *Journal of NeuroEngineering and Rehabilitation*, 12(59), 1–13. https://doi.org/10.1186/s12984-015-0055-z
Thompson, K. L., and Gullone, E. (2003). Promotion of empathy and prosocial behaviour in children through humane education. *Australian Psychologist*, 38(3), 175–182.
Warren, B., Ballenger, C., Ogonowski, M., Rosebery, A. S., & Hudicourt-Barnes, J. (2001). Rethinking diversity in learning science: The logic of everyday sense-making. *Journal of Research in Science Teaching*, 38(5), 529–552.
Yuen, S. C., Yaoyuneyong, G., & Johnson, E. (2011). Augmented reality: An overview and five directions for AR in education. *Journal of Educational Technology Development and Exchange*, 4(1), 119–140.