International Society of the Learning Sciences

Oh, I Know What to Build: Design Framing in Conversation with Materials

Madalyn Wilson-Fetrow, University of New Mexico, mefetrow144@unm.edu
Vanessa Svihla, University of New Mexico, vsvihla@gmail.com
Sherry Hsi, BSCS Science Center, shsi@bscs.org

Abstract: Because learners most commonly contend with problems that have a single right answer, learning to frame problems can be challenging. We investigated the evolution of learners' agency—shared with digital and physical materials—as they framed problems, gained coding capacity and as new materials were introduced. We collected data during one iteration of a week-long camp for children (ages 10-15, and N=15) focused on networks, design, and coding. We conducted interaction analysis of video and audio recordings. Learners who more clearly framed a design problem evaluated materials and their affordances for fit, whereas those who struggled to frame engaged in a more exploratory fashion with materials, collaboratively framing the problem in conversation with the materials.

Introduction and purpose

Summer science and engineering camps are short, but intensive supplemental learning experiences that are designed to introduce new disciplinary ideas while concurrently developing interests and skills of youth outside of formal schooling (Ramey-Gassert, 1997). The learning activities in these out-of-school learning environments are rich in material interactions for making and crafting (Dixon et al., 2019); rich in tool uses involving physical and computational tools for coding and creating digital artifacts; and project-based where campers collaboratively learn through a design challenge with peers while guided by the teacher. We were guided by the research question: How might making a new material available during the design process support learners in a coding and crafting summer camp to agentively (re)frame a design problem *with* materials? This paper shares detailed analyses of how agency shifts between campers and the teacher, and ways that affordances of materials and material engagement highly influenced learners' initial problem framing and their considerations for new alternative possible solutions.

Theoretical framework

We look to research on design and design education, highlighting the many practices designing comprises, as well as the difference—much like science inquiry—between following and directing such practices (Crismond & Adams, 2012). In contrast to the well-structured problems—problems that have a correct answer and correct method to arrive at that answer—common in instructional spaces, design problems are ill-structured and therefore require framing—the process of making decisions about what is important about the problem and the attributes of a successful solution—before they can be solved (Jonassen, 2000). Scholars define this kind of *framing agency* as making decisions that are consequential to how the problem is framed (Svihla et. al., 2021). Further, the process of framing and solving such problems is not linear, but instead is iterative and interactional, with the problem and solution co-evolving over the course of designing (Dorst & Cross, 2001).

Materials are often considered to be an extension of a designer's agency (Schön, 1984). However, agency can be negotiated with the materials themselves through the affordances of the specific material (Delbridge, 2012), which in turn are contextually apparent. This is further complicated when designing with technologies that include unfamiliar materials, as learners will tend to draft initial solutions that have little correspondence to their ultimate designs unless they can mess about with the materials first (Anning, 1994). This leads to an iterative interaction during coding and crafting, particularly in informal spaces (Dixon et al., 2019).

In classrooms, learners' agency can be influenced and shaped by facilitation, social structures and participation patterns experienced in the learning environment (Ko & Krist, 2019). Thus, to understand agency in context of engagement with materials and others will require a closer examination of learners' intended actions (design plans and intentions) and design work (enacted agency and created materials) in a facilitated learning environment to shed light on where interactions and patterns can support productive participation in design and problem framing.

Methodology

We employed design-based research to examine the theory of learning instantiated into the camp design through two iterations (The Design-Based Research Collective, 2003). We conjecture that when campers are provided with a choice of tools and materials that enable creative computational design and material construction, they engage in framing and reframing the design problem in conversation with the materials.

Participants, setting, and camp design

The camp, Radio Crafters, had 15 participants —9 were boys, 5 were girls, and 1 was nonbinary; six identified as Hispanic or Latiné, three as Asian, and six as white. Seven reported prior coding experience. We posed a design challenge: using radio, design a solution to help the Albuquerque community.

The camp took place in a makerspace classroom at a science museum in the Southwestern US. One instructor led the camp activities assisted by three researchers. The camp day had short introductory lectures about then work or craft time. In both camps, the design challenge included local context and relevant problems. Inputs for the microcontroller included button press, light or darkness, and sound. Outputs included music, communication with another microcontroller, and LEDs.

Data collection and analysis

We collected audio/video recordings, camper worksheets, instructors' reflection memos, and designed artifacts. Four static cameras and audio-recorders were positioned to each record one table; one additional roving camera focused on facilitator and whole-group activities. We then used interaction analysis to sequentially code naturally and emerging interactions and behaviors from the camp learning context to make inferences from data (Jordan & Henderson, 1995). In particular, we explore the ways that the microcontroller motor, constrained and expanded campers' considerations of their design goals. From the video analyses, we selected vignettes of campers with contrasting interactions with the materials.

Results

We consider two vignettes to explore the breadth of material conversations. The facilitators introduced the new material during the making portion of the camp. They made the material available but didn't do any specific instruction. Unlike previous inputs and outputs in the camp, these new materials didn't come with ready-made code, leaving learners to experiment with guidance rather than following specific instructions. The motor is a specific DC motor where the microcontroller provides electricity in response to an input, rotating an axle. This could then be integrated into a 3D printed chassis to make a car if desired.

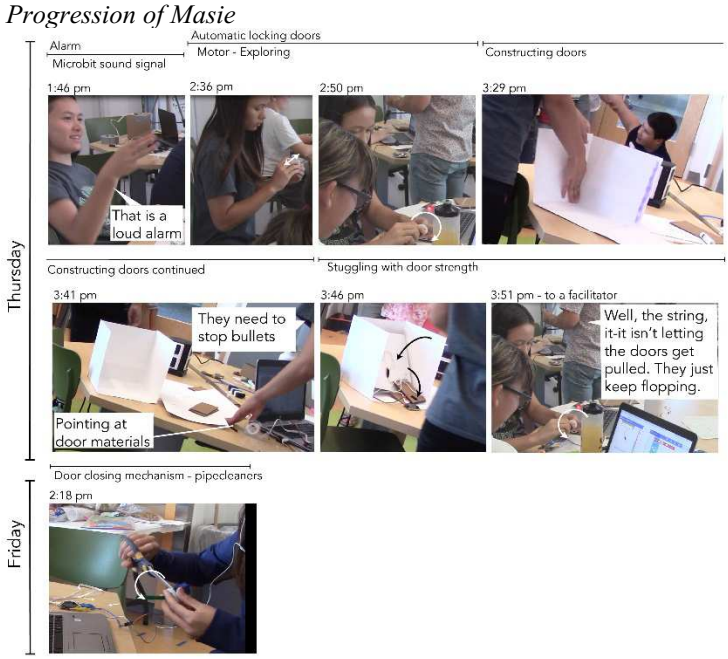
Maisie: Return to an earlier frame

Masie (13, Latinx, identifies as having "not much" coding experience) from iteration 2 framed the problem initially. She wanted to address the issue of school shootings and how to integrate safety measures into the school to respond to active shooter situations. To solve this, she initially wanted an automatically locking door however, because of the material limitations, she initially designed an alarm because radio signal and alarm noise were functions of the microcontroller she had access to (Figure 3, Thursday, at 1:46). Maisie immediately realized the new material could be used to implement her initial problem frame (security against an active shooter rather than warning people about the shooter). She tested the affordances of the material before beginning to build, examining the mechanism (2:36) and spinning the gears (2:50). Compared to the paper she crafted her classroom out of, she wanted the doors to be of a stronger material to protect against shooting (3:29 and 3:41). However, this led to different issues, when the string she thought to pull them with wasn't stiff enough, leading to collapse of the whole structure (3:46 and 3:51), leading her to rework her mechanism with pipe cleaners (Friday, 2:18).

Maisie, when presented with the motor, knew immediately what she could use it for. She retained specific framing, focusing on a single room in a school and how to make it more secure rather than attempting to solve the problem across many situations or to address the entire scope of the problem. However, the finer points of the problem-solution coevolution placed a large amount of agency on the material itself, with the material limitations forcing her to first abandon her initial idea, and then allowing her to return to it when the materials available changed. Because she wanted the doors to be thick enough "to stop bullets" tying strong to the motor wasn't strong enough in light of the amount of tension the motor could provide. Thus, she had to adapt, and the addition of the pipe cleaners as stabilizers helped her to retain her agency by introducing another material. During this she retained a high amount of agency over the frames themselves (either protecting students or alerting them) but which frame she could use was determined by the materials. She didn't revise her framings or her solutions, but instead moved from one to the other and back again.

Figure 3

Progression of Masie

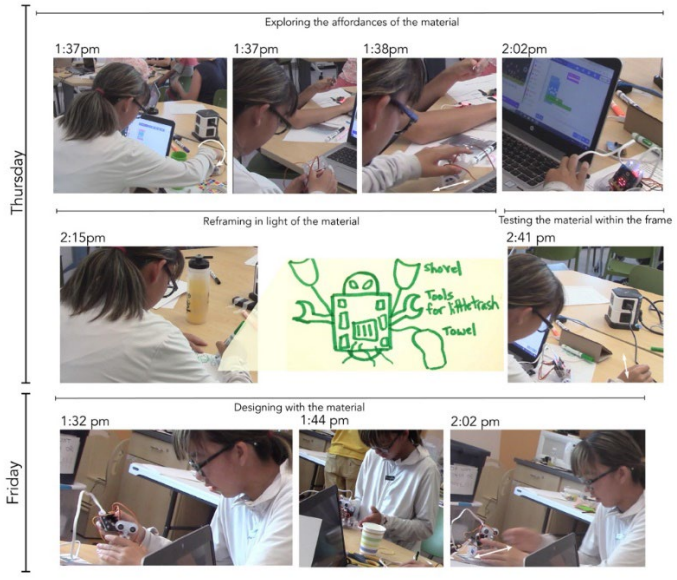


Charlotte: Framing and specifying with the material

During the ideation, Charlotte (12, Latinx/Asian, identified as having no coding experience) struggled to frame the problem specifically. She considered two problems, littering and homelessness, but thought about them in general terms. She struggled to begin designing a solution. When asked by the facilitator who handed her the car and motor what she was going to do, she shrugged and returned to her seat. She explored the material, spinning it and pulling the wires (Figure 4, Thursday 1:37) and pushing it back and forth (1:38.) Despite her initial exploration, she did not immediately begin to use the material to solve the problem, instead coding a smiley face on the microcontroller that then slotted into the car (2:02.) However, as she worked with the car, she got an idea based on the earlier general framing – a litter cleaning robot – which she drew (2:15) before beginning to construct (2:41.) She realized that the robot needed to be able to detect litter to clean it, so she focused on coding the car to be able to start and stop if it sensed something in its way (Friday, 1:32) before adding eyes and a smile to give it a friendly look (1:44) and making sure that it could stop and start fast enough to not hit anything (2:02.)

Figure 4

Progression of Charlotte.



Charlotte approached the material much more generally than Maisie and took a path of exploration. While she had framed a problem (too much litter), it was much too broad to consider solutions. The material supported her to reframe more narrowly (cleaning up litter that already exists) but did not result in as specific a frame as those who had used the material to support an existing specific frame, even when all engaged in some amount of reframing. She was able to identify that her initial product (a smile mounted into the vehicle) was context-less and wasn't a solution to the design problem. As she reframed her broad idea into a more specific one, then again as she went from a more ambitious idea that didn't take materials into account to one that worked with the materials, she identified elements of the design that were contextual. Charlotte identified that her robot needed to look friendly, adding googly eyes. As she engaged with the material, her conceptualization of the problem she framed became more and more specific, identifying more design constraints and considering more stakeholders.

Discussion and implications

Learners who more clearly framed a problem with stakeholders and situations subsequently evaluated the available materials and their affordances. Ultimately, contextualizing the design is what led to determination of if the material was useful. Although we documented willingness to improvise and make solutions work, upon encountering a material whose affordances seemed better fit to the situation, they readily changed their design to incorporate the materials. A desire to use the material did not result in abandonment of the design context, though it continued to remain much more general. The implications of these findings suggest that materials have agency and selection of materials can impact collaborative design outcomes. This can be leveraged to support designer agency, in ways that are collaborative. Further, the design context and the affordances of materials are in conversation with the designer, with each impacting the other during the ongoing design process. The agency of the learners allows for reframing during this process. What remains less clear from this work is the role of both designer interest and background skill in the process. Because the introduced material was new to the learners, it remains unclear how more experience might impact the agency of the materials

References

Anning, A. (1994). Dilemmas and opportunities of a new curriculum: Design and technology with Young Children. *International Journal of Technology and Design Education*, *4*(2), 155–177.

Crismond, D. P., & Adams, R. S. (2012). The informed design teaching & learning matrix. *Journal of Engineering Education-Washington*, *101*(4), 738.

Dixon, C., Schimpf, C. T., & Hsi, S. H. (2019). Beyond Trial & Error: Iteration-to-learn using computational papercrafts in a STEAM camp for girls. *2019 ASEE Annual Conference & Exposition*.

Dorst, K. (2003). The problem of design problems. *Design Thinking Research Symposium Proceedings*, 17(19.11).

Gibson J. J. (1977). The theory of affordances. In Shaw R., Bransford J. (Eds.), *Perceiving, acting, and knowing: Toward an ecological psychology* (pp. 67–82). Hillsdale, NJ: Erlbaum.

Jonassen, D. H. (2000). Toward a design theory of problem solving. *Educational Technology Research and Development*, *48*(4), 63–85. https://doi.org/10.1007/BF02300500

Jordan, B., & Henderson, A. (1995). Interaction Analysis: Foundations and Practice. *Journal of the Learning Sciences*, *4*(1), 39–103. https://doi.org/10.1207/s15327809jls0401_2

Ramey-Gassert, L. (1997). Learning Science beyond the Classroom. *The Elementary School Journal*, *97*(4), 433–450.

Schön, D. A. (1984). Problems, frames and perspectives on designing. *Design Studies*, *5*(3), 132–136.

Svihla, V., Peele-Eady, T. B., & Gallup, A. (2021). Exploring agency in capstone design problem framing. *Studies in Engineering Education*, *2*(2). https://doi.org/10.21061/see.69

The Design-Based Research Collective. (2003). Design-Based Research: An Emerging Paradigm for Educational Inquiry. *Educational Researcher*, *32*(1), 5–8.

Acknowledgments

This material is based upon work supported by the National Science Foundation under Grant Nos. 2053160 and 1751369 and institutional funding. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.