# Expanding the Maker Movement by Recentering "Building for Others" in Construction Activities

Nathan Holbert, Teachers College, Columbia University, holbert@tc.columbia.edu
Sawaros Thanapornsangsuth, Teachers College, Columbia University, st2839@tc.columbia.edu

**Abstract:** The goal of the Bots for Tots project is to develop theory around the role of activity framing on diverse participation in making and construction practices. In Bots for Tots, a design-based research project in three locations over two years, builders create a "dream toy" for a younger member of their local community. We hypothesized that building for others would appeal to young girls that may not typically see building robots and racecars as aligning with their goals and values. Data indicates participating girls consistently considered their "client" throughout the design process and were interested in continuing to build for others after the project ended. We show how the degree to which the "other" impacts the construction process depends on the quality of the relationship between builder and client. We propose recentering "women's ways of knowing" in maker practices to broaden participation among women in STEM domains.

## Introduction

The "maker movement" has become an international phenomenon. No longer just the purview of a handful of technology enthusiasts, the opportunity to design and produce unique artifacts using high tech prototyping equipment such as 3D printers, laser cutters, and microcontrollers has extended beyond the garage and university laboratory. Schools and educational programs have embraced so-called makerspaces in hope of leveraging these tools and activities to engage young people in STEM domains and practices (Halverson & Sheridan, 2014). Despite this exciting development, longstanding traditions of "making"—such as sewing and textile work that has traditionally been performed by women—have mostly been ignored in the mainstream face of the movement (Buechley, 2016), leaving many to question whether the embrace of the maker movement by educators will help to address or exacerbate the overwhelming gender gap in STEM domains. Enthusiastic about the cognitive and sociocultural possibilities enabled by construction activities (Papert, 1980), we propose that when making is framed as leveraging multiple epistemologies, ways of knowing, and diverse materials and practices it can be a powerful method of connecting diverse learners to STEM domains.

The goal of the Bots for Tots (BfT) project is to develop theory around the role of activity framing on diverse participation in making and construction practices (Holbert, 2016). Specifically, we seek to identify the ways in which making for others impacts when and how young girls engage with construction activities. BfT was conceived of as design-based research and implemented over two years in three locations. At the core of the BfT project is a shift from the typical maker activity which has learners make something for themselves to instead have builders create a "dream toy" for a younger member of their local community. We hypothesize that building for others will appeal to young girls that may not see STEM domains as aligning with their goals and values. In this paper, we present data from implementations conducted over two years and show how the "other" was a constant focus of young builders as they first became motivated to participate in the project, as they overcame obstacles as part of the design process, and as they considered additional construction opportunities beyond the BfT program.

## Theoretical framework

Despite an explicit focus by education researchers, practitioners, and policy makers, women make up a small segment of the STEM workforce. Recent surveys suggest women hold just 25% of computing occupations and make up only 15% of the engineering workforce (NSF, 2015; NCWIT, 2015). Many factors contribute to this gender gap including a misogynistic culture that pervades STEM workplaces (Posner, 2017; Ratcliffe, 2015), the low number of female role models and support (Margolis & Fisher, 2003), as well as a misalignment between the values and goals held by many women and their perceptions of the work of STEM domains (Diekman et al., 2010; Intel, 2014).

As maker activities have become a popular method of engaging young learners in STEM practices, it is important to make clear that the popular "maker movement" has major diversity issues. For example, 70% of those attending the 2014 Maker Faire in San Francisco were men, an overwhelming 97% had college degrees, and attendees had a median household income of $130,000 (Maker Media, 2014). Examining the 53 covers of all *Make:* magazines published over 10 years, Buechley (2016) found that only 16% showcased women or girls.

One promising avenue for addressing the recent and narrow definition of making popularized by *Make:* has been to recenter making practices such as sewing and paper crafts that have existed for centuries and have traditionally been performed by women. This effort has included the design of new tools and technologies such as the Lilypad Arduino that brings computational power to textiles (Buechley, 2006), as well as a diverse array of workshops and activities that engage young women in designing electronically embedded clothing (Kafai, Fields, & Searle, 2014; Peppler & Glosson, 2012). Materials and tools are cultural artifacts that communicate gendered expectations. By expanding the possibilities of what these tools and materials can do, we expand what counts as legitimate STEM activity.

This work has pushed the research community to look beyond the overtly masculine definition of STEM to include the unique practices and values of the visual and manual Arts. And yet, too often the important intellectual contribution of these programs of research are oversimplified in practice and reduced to robots for boys and fashion and e-textiles for girls (Kafai et al., 2014; Kafai & Peppler, 2014). Consequently, our work has sought to further broaden this design space by considering not just the materials and tools of construction, but also the underlying values and motivation at the heart of making. Not just "who makes and with what," but also "why and for whom?"

We find Belenky et al.'s (1986) work on women's ways of knowing a compelling framework for reframing the value and goals of making to be about building connections. They argue that women are often driven by the desire to connect with knowledge and with "the other" at a personal level—that "connected knowers learn through empathy" (p. 115). Though these values are not restricted to women (and some women may value traditionally "masculine" activities and practices), these ways of knowing are ignored by STEM practitioners or worse, actively disparaged and belittled (Posner, 2017; Ratcliffe, 2015). Evidence of the value of reframing these activities to focus on contributing to one's community can be found in the project-based service learning literature. Schools of engineering that have adopted project-based service learning have found greater success in both recruiting and retaining women and other underrepresented groups (Barrington & Duffy, 2007; Swan, Paterson, & Bielefeldt, 2009).

## Methods

The BfT project was designed to engage young makers (builders) in building toys for other children in their community (clients). This project was conceived of as design-based research (The DBR Collective, 2003) and implemented iteratively over two years in three different locations, with each iteration evolving to address unique challenges and contexts and in response to ongoing data analysis. The design-based research methodology allows us to compare iterations of the BfT design across each version and between contexts thereby informing theory at the intersection of the design and student learning.

In the first year of the project, all 4$^{th}$ grade students (ages 9-10) from a public elementary school in a large urban city in the US were invited to attend a series of five free Saturday workshops where the goal would be to "build new toys for younger kids in your school." These workshops were run by the first author and were held in a maker lab in the first author's academic institution. While all 4$^{th}$ grade students received the flyer advertising the workshop, due to space constraints only the first ten to respond and schedule a pre-workshop interview were invited to participate. One participant that was interviewed was unable to attend the workshops resulting in nine participants (seven girls and two boys). In this paper, we will refer to this implementation as "Y1 Public."

The following year, BfT was re-designed, in collaboration with a teacher partner, responding to findings from our first implementation (extensive details about the design changes can be found in Holbert et al., 2017). In one of these implementations, BfT was once again presented to 4$^{th}$ grade students from the same public elementary school as in Y1 Public. However, in this implementation, BfT was structured as an afterschool club that met weekly for 1.5 hours during a semester resulting in 12 total sessions. Because afterschool clubs are often used as childcare, and the school controlled the sign up process, it is likely that parents signed their children up to participate, rather than the students choosing to participate based on interest. This sign up process resulted in eight total participants (six boys and two girls). The BfT afterschool maker club was located in the school's library and was facilitated by the second and first authors. We will refer to this implementation as "Y2 Public."

In the second year, we also implemented BfT in an all-girls private school in a nearby suburban community. This implementation was run by our teacher co-designer who is employed by the school as the visual arts instructor and was held in the school's expansive "Design and Engineering Lab." All 4$^{th}$ grade students were required to participate in the BfT project resulting in 41 girls (ages 9-11) spread across two classes. Each design session lasted 45 minutes and occurred approximately twice a month throughout the year for a total of 18 sessions. In this paper, we will refer to this implementation as "Y2 Private."

All Y1 and Y2 making sessions followed approximately the same overall structure shown in Table 1. Introduction sessions introduced participants to the tools and techniques they would use throughout the workshop. Following these introductory activities, builders interviewed their clients about their dream toys asking: "What kind of toys do you like? If you could imagine any toy, what would it look like and how would you play with it?" The next sessions included opportunities to brainstorm possible toy designs that would meet the requests of the clients, prototyping, and eventually building the final toy. Finally, builders delivered their newly constructed toys to their clients during a "play date." Two important changes to the BfT implementation in Y2 included allowing builders to revise their target client in Y2 Public and the addition of a client feedback and reflection session in Y2 Private.

Table 1: While the overall structure of each BfT implementation did not change, additional opportunities to interact with the clients and reflect on design ideas was added in year two

<table>
<tr><th>Y1 Public (3 hr sessions)</th><th>Y2 Public (1.5 hr sessions)</th><th>Y2 Private (45 min sessions)</th></tr>
<tr><td rowspan="2">Introduction<br>Omnianimal (wood)</td><td>Introduction<br>3D card</td><td rowspan="2">Introduction<br>Omnianimal (cardboard) x 3</td></tr>
<tr><td>Omnianimal (cardboard) x 2</td></tr>
<tr><td>Client Interview (20 min)</td><td>Client Interview (20 min)</td><td>Client Interview (20 min)</td></tr>
<tr><td rowspan="2">Brainstorm</td><td>Collage of Client Interests</td><td rowspan="2">Brainstorm x 2</td></tr>
<tr><td>Revise Client<br>Brainstorm</td></tr>
<tr><td rowspan="2">Prototype</td><td rowspan="2">Prototype x 2</td><td>Prototype x 2</td></tr>
<tr><td rowspan="2">Client Feedback<br>Design Revision</td></tr>
<tr><td rowspan="2">Build Final Toy</td><td rowspan="2">Build Final Toy x 3</td><td>Build Final Toy x 7</td></tr>
<tr><td>Play date (30 min)</td><td>Play date (30 min)</td><td>Play date (30 min)</td></tr>
</table>

Each session was video recorded and detailed field notes were taken by researchers present in the room. The research team conducted semi-structured interviews with participants to determine makers' prior experiences with technology, construction, and crafts as well as knowledge of relevant concepts or skills. In Y1 Public, most all participants were interviewed both before and after the workshop. In Y2 Public, all participants were only interviewed before the workshop due to scheduling difficulties. Twelve participants were randomly selected to be interviewed before and after the BfT implementation in Y2 Private. Interviews were video recorded and transcribed. Transcripts were coded "bottom-up" where coding categories emerged from patterns in the data. A subset of the codes relevant to this analysis were applied by outside coders. Interrater reliability was computed for each data set with all sets achieving greater than 0.7 Cohen's Kappa initially and improving to greater than 0.9 after discussion.

A large number of artifacts were produced throughout this project. These include worksheets (My Client Profile, client feedback, etc.) and notebooks completed by the builders, photographs and roaming video recordings of participants working on their projects, and photographs of toy designs throughout the construction process. These artifacts provided a broad picture of each participant's work, such as whether they worked independently or alone, as well as their level of expertise both in technique and constructed toy.

## Results

The central hypothesis of the BfT program was that building for others would be a compelling way of framing the value of making for young girls. We expected that young girls might be excited to work with younger children in their community, but also assumed that the quality of the builder-client relationship would impact the degree to which this activity felt meaningful to the builders. Each implementation provided a different builder-client relationship which allowed us to interrogate the role this relationship played throughout the construction process.

### Bots for Tots year one

In the first implementation of the BfT project, we invited 4th grade builders to create toys for pre-Kindergarten (pre-K) children (age 4) in their school. Because the number of students in the pre-K class was greater than that of the builders in the BfT project, Y1 Public builders were broken into groups of two and paired with five to six pre-K clients. Consequently, when the builders first interviewed their clients and asked them to describe their dream toys, each pre-K child described a different toy resulting in a large number of highly diverse requests. For example, one set of requests included a Pinky Pie pony, a phone, and a monster truck race car.

Rather than abandon some ideas in favor of a more coherent design, teams took seriously each request by the children. Some groups addressed this difficulty by combining many ideas into one toy, such as Tayla and Inez's "shopkins" plane car. Others chose to create multiple objects that could work together to satisfy the design requests. For example, Kelly, Raquel, and Kyle created a toy that included a Pinkie Pie pony doll phone that rides a monster-truck-skateboard (Figure 1).

Figure 1. Groups took the many diverse requests by the clients seriously, going as far as to merge a variety of ideas into multiple toys that worked together, such as the Pinkie Pie pony doll phone that rides a monster truck skateboard.

The desires and requests of the clients also played a role in early phases of the construction process. When making design decisions about toys, teams often took on difficult tasks to meet the requests of the pre-K client. For example, when trying to decide which materials to use when making the wings and wheels of a toy plane, a builder from another team suggested something "squishy" so that the toy would be pleasant to cuddle. Another designer quickly spoke up stating, "I disagree that the wings should be squishy! Cause isn't it an airplane and is supposed to fly? So how's it going to fly if the wings are squishy!"

When eight Y1 Public builders were interviewed after the project (one of the girls was unable to schedule a post-interview), three builders expressed some disappointment in what they created and six indicated they would like to continue to add to or modify their designs. However, all eight interviewed children told us they felt their design was a success. For example, Juan stated, "I felt happy because the kids were happy and they were like each one were playing with the toys!" Similarly, when asked if they'd rather make for themselves next time or for someone else, five of the six girls interviewed told us they'd prefer to make for someone else (due to an error made by the interviewer, one of the girls was not asked the question during the interview, though responding to what made her proudest, she stated she liked seeing the kids' faces, ''it was so nice!'').

## Bots for Tots year two

In the second year of implementations we sought to increase the personal nature of the client-builder relationship. Y2 Private offered a unique opportunity to leverage an existing mentorship program that had the 4th grade girls of the school mentoring 1st graders (age 6) throughout the year. Using this existing program, our BfT implementation in this school paired each 4th grade "Big Sister" 1:1 with her 1st grade "Little Sister" client (because of uneven numbers, one client had two builders). The builder-client pairs interacted multiple times throughout the school year (in addition to those facilitated by the BfT project) which allowed each builder to get to know the interests and personality of her client. This relationship was central to how and what the Y2 Private builders created.

Early in the semester builders interviewed their clients asking them to describe a dream toy. Using a "client profile sheet" builders were encouraged to identify the interest and likes of the client—including toys, materials, colors, etc.—as well as any objects or things they do not like. In a few cases, this interview provided builders with a precise specification for a dream toy to be built—for example Ava's client indicated she wanted a "pop out monster car." In most cases, however, this interview provided a list of potential toy features or possible toy properties that could become part of a toy design. For example, Chloe's client profile sheet suggested her client likes stuffed animals, bounce balls, Magna-Tiles, and drawing, and does not like sharks.

Using these lists, builders brainstormed toy ideas that might satisfy the requests of their clients and drafted lists of materials and tools they might need to create this new toy. For example, Chloe starred "stuffed animal" and "draw" on her list of toys and activities provided by her client. She then brainstormed ideas that included extensive details about the materials and colors she would use in her construction. While Ava knew she was to build a "pop out monster car," a variety of concerns would need to be considered. For example, Ava chose to make the car out of wood, planned to include a "squishy guy" with a "funny wig," and intended to have the car play music and light up when used. Ava's description also included a constraint expressed by her client, "No pink or purple on or in the car."

Brainstormed ideas were eventually translated into a simple prototype which was then shown to the client to gauge her interest in the design and to received feedback and suggestions for the final dream toy. Occasionally, the client simply provided additional ideas such as "more eyes" for Ava's pop up monster car and "fluffier" for Chloe's whiteboard bunny. However, others requested large changes. For example, when Ruth presented her client with a prototype of a pillow with a voice recorder that spoke "I love you!" when squeezed, her client told her she would prefer a doll house. Ruth was initially disappointed, but after some encouragement from her classmates, she was soon back on track sawing sheets of plywood to build the new toy requested by her client.

Incorporating this feedback into their designs, the 4th grade builders then constructed the final toy over a few weeks and eventually delivered these toys to their clients in a final "play date" at the end of the year. Of the 40 projects being built by Y2 Private builders, 26 of them stayed consistent from the brainstorming phase all the way to the final toy construction. 14 of the builders made changes after the initial brainstorm phase or after receiving feedback on their prototype from the client. The reasons for these changes varied. Three of the 14 altered their design because they became enamored with a different material or because the materials available did not meet the requirements of their designs. Two of these girls changed their design due to requests by the client. For example, Sari had originally planned to make a stuffed talking monkey as requested by her client. However, when playing with the prototype her client informed her she would rather have a white talking sheep. Sari used this feedback to alter her final toy design and produced a beautiful white fluffy sheep (Figure 2).

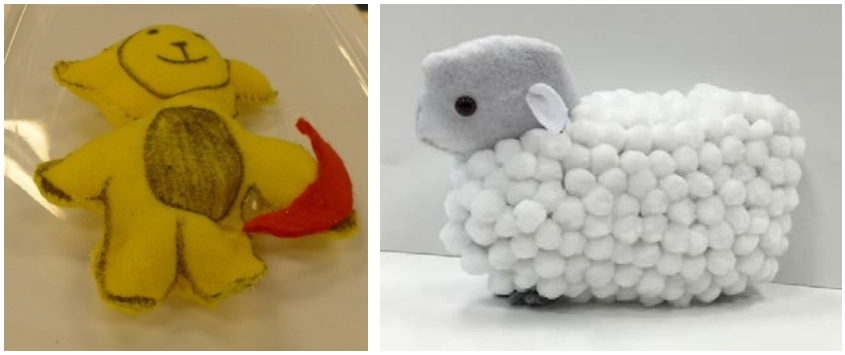

Figure 2. Many girls altered their designs between the brainstorm, prototype, and final construction phases—such as Sari's shift from a monkey to a sheep design seen here—due to requests made by the client.

Eight of the 14 that altered their designs between the brainstorming and final toy stage did so because they had difficulty achieving the goals they set out in their design. These challenges varied from sawing wood the correct length to cutting fabric for different shapes for stuffed animals. All eight of these girls instead chose to make a pillow for their clients (an activity they had done in class the previous year). While the pillow design was not the design originally requested by the clients, all eight designs were personalized for each client and incorporated features that were requested, such as using the client's favorite color, sewing the client's name into the pillow, or drawing pictures that were of interest to the client.

After the year-long project, 12 randomly selected Y2 Private participants were interviewed. Similar to Y1 Public, we asked participants if in a future BfT project they would prefer to build for themselves or for someone else. Ten of the 12 girls said they would like to make for others. LillyJane told us, "I like making stuff for others because I love seeing their reactions." Panni explained, "Well, they really appreciate what I make for them and I love hugs and they give me hugs!" Five of these 10 girls expressed interest in making something for themselves as well as others. Two told us they'd prefer to just make something for themselves next time. These girls felt proud of the toy they had made and were sad to part with their construction.

Y2 Public offered a different set of results regarding the role of the client in the builders' designs and construction processes. As with the other conditions, we had planned for builders to create dream toys for

younger children in their school. Similar to Y1 Public, we created teams of two builders and provided an opportunity for them to interview 5-6 pre-K clients. As builders worked to document their clients' likes/dislikes in the construction of a collage, it became clear that they had little interest in building the toys requested by the pre-K children. One boy felt the "squeaky gem toy" requested by his clients was boring, others seemed more interested in making a collage using pictures relevant to the then upcoming 2016 presidential election.

As the goal of the project was to leverage builder's goals and values in the making process, we allowed builders to choose new clients. Because anxiety was high for children in this school—which includes many immigrant families—after the 2016 presidential election, we suggested builders might create toys for people they were close to as a way to show they cared. Builders then generated a new list of potential clients. All builders included their friends (five of which included other people in the class) on their potential client list. Two also listed their mothers and two listed the pre-K clients they had interviewed previously.

After choosing new clients, Y2 Public builders became reenergized about the construction process. One of the groups continued to build for their pre-K clients, creating and sewing a stuffed T-Rex monster that met the original requests of the pre-K clients they had interviewed. Another builder chose to work alone to create a toy train for one specific pre-K student that was the younger brother of a fellow BfT builder. Two other groups and a third solo builder chose to make toys for their friends.

## Discussion

The BfT project sought to examine the impact of leveraging "ways of knowing" to increase young women's participation in construction activities. The results above highlight how the changes in implementation design as well as the school and wider communal context impacted the young makers' interests in building for others. While the idea of making for others was compelling for most girls (and some boys) in all three implementations, the degree to which this framing impacted practice and future interest varied by context and design.

Y1 Public provided an existence proof for the notion that building for others might be a compelling way to engage young girls in construction workshops, and the Y2 implementations allowed us to make several modifications to the design of the project to further interrogate key features of the project system. In particular, Y2 Private allowed us to examine a one:one builder-client ratio and in Y2 Public we replicated the few:many builder-client ratio from Y1. We find that the quality of the relationship between builders and clients matters a great deal. Specifically, while nearly all young girls found making for others compelling, when able to make for one specific person, rather than many at once, builders more frequently considered the client's interests in all phases of the design process.

In Y1 Public, teams of two to three builders took on the task of creating a dream toy for five to six pre-K children. While teams rarely mentioned individual pre-K children, during the brainstorm phase they took each request by their pre-K clients seriously. As indicated in the results section, this meant that teams often created many toys that worked together, or one toy that blended each idea into one artifact. However, this attention to the client took place almost exclusively in the brainstorm phase. Once teams identified a project idea, the client was only occasionally mentioned. When the client was mentioned, it was often to motivate team members that were not contributing equally.

While the results from Y1 Public were compelling, in Y2 we intentionally set out to better support the relationship between builders and clients to reflect Belenky et al. (1986) connected knowing—women's tendency to value social interactions and a sense of community. Leveraging the Big/Little Sisters program ensured builders would not only encounter their client more frequently (they shared the same building and often met outside of class time), but also be encouraged to develop a mentor-like relationship providing care and guidance to their client as it was their first year of elementary school. This intimacy seemed to motivated the builders throughout the making process. For example, Hailey said in the post interview that she "really wanted to make something that [her client] would remember and really love." Kate told us she sometimes asked her clients during recess if she still wants a doll to make sure that she was making it right for her.

In all three iterations builders had a high degree of flexibility in what they made. While they were encouraged to make the client's dream toy, there was no metric or standard to measure their adherences to this program goal. However, all builders, made some effort to do so. In Y1 Public, builders took on challenging and even occasionally impossible design tasks. The one group that struggled to complete their design on time, reconceptualized their project as a DIY for their clients creating an opportunity for the builders and clients to build together during the play date (Figure 3). In Y2 Private, client feedback and reaction had both positive and negative impact on the builders and drove their design decisions. As shown in the results section, Chloe's client liked her whiteboard bunny so Chloe only made minor changes to her design; while Ruth changed her project entirely when her client expressed dislike for her pillow prototype. Out of 40 Y2 Private projects, 39 were personalized to their clients. In Y2 Public the lack of interest in the initially assigned pre-K clients caused some

builders to lose interest in the project all together. After allowing participants to choose new clients, each team became motivated to persist through the design process. While we did not see the same degree of commitment to the client as that of Y2 Private, nor did we see the complex designs of Y1 Public, designers did produce complete and compelling artifacts aligned with what they believed to be the interests of their clients (Figure 3).

Figure 3. A Y1 Public team (left) made a "DIY" toy so they could build *with* their clients and a Y2 Public team stuck with their pre-K clients even when they weren't initially interested in building the toy requested.

Finally, while most of the girls found building for younger children in their school community compelling, some did not. The two girls in Y2 Private that suggested they would prefer to make for themselves next time indicated that they were sad to part with a project for which they had worked so hard. One girls explained by stating, "I mean once you make something, I kind of like to keep it so I can like admire it." Likewise, many of the boys did not find the pre-K clients compelling. One of the Y1 Public boys told us he would like to make a toy for himself. The other boy in this implementation indicated he would like to make a toy for his younger brother rather than the pre-K children he did not know very well. Two of the Y2 Public boys happily made toys for the pre-K children, while the other four preferred to make for a friend or family member.

In each of the three implementations, making was explicitly framed as a way of giving to others. However, the reason for giving depended on more than the gender of the builder. In Y1 Public, builders created toys as a gift to younger members of their community. The relationship between builder and client was modest, but effective at driving initial construction activity. This relationship was enhanced by leveraging the mentor-mentee relationship in Y2 Private. For these girls, building a dream toy became a way of representing and strengthening this mentor-mentee relationship. While we assumed our activity framing from Y1 Public would work similarly in Y2 Public, we instead found external social and political pressures meant a narrowing of what counts as one's community. For Y2 Public builders, existing personal relationships were paramount, and making was a way of reinforcing that relationship.

These results suggest that while framing making as a way of building connections to one's community will likely be compelling for young makers—and girls in particular—the degree to which this framing drives the making process will depend on who builders see as being part of their community and the quality of that connection. We suggest designers of maker activities *should* leverage "making for others" as a way of increasing participation and persistence among girls in maker activities, while also acknowledging the challenge of determining a compelling "other." In addition to using the existing research literature, as we did for Y1 Public, we recommend designers seek to both connect with existing community programs as well as build into the activity design opportunities for participants to express with whom they desire to connect.

## Conclusions

Women have been makers for centuries. And yet, the recent conceptualization of "making" elevated by the maker movement and pushed by tech companies, startup culture, and schools alike often legitimizes masculine construction activities and materials over those traditionally performed by women. As these maker activities have become a primary way of engaging young learners in STEM domains, this new definition of making must be challenged.

One method to address this overtly masculine definition of STEM has been to design maker and STEM workshops that focus use traditionally feminine materials and interests. We propose to further broaden this effort by recentering women's ways of knowing in maker practices. In our work, we have found that when making is framed as being a way of building connections to one's community, young girls are likely to see these activities as aligning with their values and goals.

Of course, ways of knowing and connecting will vary along a variety of dimensions. For some this connection may be strongest when positioned in a mentorship roll—as we saw in our own Y2 Private implementation—while for others, building for family or a friend may be most compelling. But making and construction isn't only an interaction between builder and tools or materials. Both bring with them cultural expectations, goals, and values. Future efforts to broaden participation in STEM domains through making and construction must acknowledge and center the values and goals of diverse learners in both design and implementation.

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