

CHALLENGES AND TRADEOFFS WHEN ENGAGING YOUNG MAKERS WITH CONSTRUCTING FOR OTHERS

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As makerspaces and fabrication labs enter schools as a means of motivating children to explore STEM fields, the lack of diversity in engineering and computing must be addressed. The Bots for Tots project explores the potential of leveraging deeper values and perspectives in making practices by engaging young children in designing and creating objects for others rather than for themselves. In this design case, we present outcomes from the first Bots for Tots implementation highlighting key design challenges and tradeoffs for (a) encouraging a personal relationship between builders and clients while retaining design complexity, and (b) ensuring productive prototyping while providing materials and tools with which designers are familiar. We also discuss revisions for a second iteration where we leverage an existing mentorship program to ensure close designer-client relationships, and constrain material choices throughout the construction process to encourage participants to focus on function and process during prototyping.

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INTRODUCTION

Makerspaces and fabrication labs have become a popular method of engaging both adults and children with new high-tech prototyping tools and technologies as well as a do-it-yourself (DIY) mentality. Research has shown these activities to promote important values and practices such as creativity, problem-solving, collaboration, self-expression, and computational literacy (Berland, 2016; Blikstein, 2013; Halverson & Sheridan, 2014; Kalil, 2013; Papert, 1980). With the expansion of Maker Faires, high profile DIY publications and websites, as well as the home commercialization of equipment such as 3D printers, educators and policy makers have begun to take note of the possibility of leveraging this movement to motivate children to explore STEM fields.

While Maker Faires and public outlets for DIY activities have continued to expand (Nesta, 2015), these venues have overwhelmingly focused on typically masculine projects like robots, race cars, and rocket ships (Buechley, 2013; Maker Media, 2014; Moilanen, 2012). This tendency to market directly to such a narrow population is problematic as making becomes a popular method of engaging young people in STEM domains. Recent data indicates women make up only 26% of the computing workforce (NSF, 2017) and 15% of practicing engineers (NCWIT, 2015). Black and Hispanic men and women are even less represented in science and engineering professions (4.8% and 6.0% respectively; NSF, 2017). As our society becomes increasingly driven by software, the lack of diverse representation among those that can read, interpret, and shape digital technologies leads to greater inequality and physical and virtual spaces that actively discriminate against non-dominant perspectives and values.

The Bots for Tots project explores the impact on learners' identities around making and technology when maker activities incorporate learners' values, rather than simply interests. Like many other efforts to engage children in making, the Bots for Tots project employs a constructionist paradigm (Papert, 1980; Papert & Harel, 1991), offering a space for personally meaningful explorations of materials and ideas with the goal of publicly creating something new and of value. However, Bots for Tots was designed to explicitly leverage

what Belenky, Clinchy, Goldberger, and Tarule (1986) call “women’s ways of knowing” to engage young makers in creating objects for others, rather than for themselves. With the hope of increasing diversity in makerspaces as well as STEM more broadly, many scholars have actively sought to engage underrepresented groups in making and design. These efforts include creating new hangout centers for children in low-income communities to engage in creative design and construction with digital technologies (Pinkard, Barron, & Martin, 2008; Resnick, Rusk, & Cooke, 1998); new tools for connecting coding to traditional feminine practices and craft communities (Buechley, 2006; Buechley & Perner-Wilson, 2012; Kafai & Peppler, 2014; Qi, Huang, & Paradiso, 2015); and technologies and workshops targeted specifically at underrepresented groups (Stern, Reid, & Bancroft, 2015). Our work builds on these efforts with the explicit goal of exploring the potential of leveraging deeper values and perspectives in making practices. Our goal is to avoid activities and tools that imply two versions of engineering and computing (Kafai, Fields, & Searle, 2014)—one for girls and one for everyone else—and rather to expose young makers to the idea that these domains leverage multiple epistemologies and ways of knowing.

This paper presents a design case examining the key design features, challenges, tradeoffs, and outcome of the first iteration of the Bots for Tots workshop for nine fourth-graders from an urban school in a Northeastern U.S. city. We focus on two challenges. First, we highlight efforts to leverage values of “helping others” and “giving back to one’s community”—values women frequently cite as absent from STEM professions (Diekman, Brown, Johnston, & Clark, 2010; Intel Corporation, 2014; Konrad, Ritchie, Lieb, & Corrigall, 2000)—by encouraging a personal relationship between builders and clients. Second, we discuss design choices made to

assist workshop participants as they manage transitions between phases of the design process. Lessons learned from the first implementation as well as alterations made for a second implementations of the Bots for Tots project are discussed for each challenge.

BOTS FOR TOTS PROJECT OVERVIEW

Drawing from feminist theory (Belenky et al., 1986) and research in project-based service learning (Swan, Paterson, & Bielefeldt, 2009), Bots for Tots positions making as a way to build connections between individuals and to leverage engineering practices to “give back” to one’s community (Intel Corporation, 2014). At its heart, the Bots for Tots project engages young makers in creating objects or toys for younger children in their immediate community. As such, Bots for Tots shares many common features of other maker workshops but differs in the centrality of the designer-client relationship. This design choice is central to our hypothesis that young girls would be likely to see making as valuable and interesting if it is framed as being about helping others.

The overall project aim is to empower diverse learners to see themselves as individuals who can do and make things of value. We accomplish this by engaging learners in developing a relationship with younger children in their school and then building a toy for these young “clients.” Table 1 shows how our project goals shape our design intentions and expectations of the project.

Nine fourth-graders (seven girls and two boys) were recruited by flyer from a public school in a highly urban Northeastern U.S. city to participate in a free maker workshop that would meet over the course of five Saturdays. Recruitment materials highlighted the use of high-tech

PROJECT GOALS	DESIGN CHOICES	EXPECTED OUTCOMES
Build personal relationships between fourth-grade designers and Pre-K clients	<ul style="list-style-type: none"> Engage fourth-graders in designing and creating toys for pre-K children. The fourth-grade designers meet and interview pre-K children to learn about their toy preferences at the beginning of the workshop. The fourth-grade designers give the toys they designed for pre-K children and play with them on the last day of the workshop. 	<ul style="list-style-type: none"> The fourth-grade designers would feel a personal connection to their client. Throughout the construction process the designer would consider the interests and desires of the client and be motivated to create something the client valued.
Create personally meaningful objects	<ul style="list-style-type: none"> Engage learners in a design process that includes brainstorming and prototyping. Allow builders to be hands-on with high tech fabrication equipment. Provide construction materials that the learners have likely used previously. 	<ul style="list-style-type: none"> Although the designers will take into consideration the clients’ preferences, the constructed toy will be unique and reflect the choices they made throughout the design process.

TABLE 1. Bots for Tots project goals, design choices made to address those goals, and expected outcomes.

fabrication tools (e.g., 3-D printers, laser cutters, iPads with drafting app) and explicitly indicated participants would be building toys for younger kids in their own school. A pre-kindergarten (pre-K) class at the school was recruited to serve as “clients” for the fourth-grade designers.

The full research team consisted of the first author and seven graduate students (including the second and third author). The first author ran each session with other team members rotating, so no more than four facilitators were present for each session. Only one workshop was facilitated by two men, while the others were facilitated by one man (the first author) and three women.

Fourth-grade participants followed the design process throughout the workshop—interviewing clients, brainstorming ideas, making tangible prototypes, and building a final product (see Table 2). During client interviews, the fourth-grade designers asked the pre-K children to describe their “dream toys.” Example questions included, “If you could have any toy, what would it be? What material would it be made of? How would you play with it?” After interviewing their clients, designers reported on their interview to their classmates and brainstormed toy design ideas. Collectively, they gave each other suggestions and feedback.

SESSION GOAL	LENGTH	MAJOR ACTIVITIES
Introduction	4 hrs	<ul style="list-style-type: none"> Pre-workshop surveys Introduction to tools Design and build omni-animal
Pre-K Interviews	20 min	<ul style="list-style-type: none"> Interview 4-6 pre-K children about their “dream toy”
Brainstorm toy design ideas	3 hrs	<ul style="list-style-type: none"> Report on interviews Individually brainstorm ideas Group discussion and idea sharing Begin paper prototypes
Build Prototypes	3 hrs	<ul style="list-style-type: none"> Revisit design ideas Continue prototyping Show and tell/critique Begin design of final toy
Complete Toy	3 hrs	<ul style="list-style-type: none"> Discuss final plans as a group Finalize toy construction
Toy delivery and play date	20 min	<ul style="list-style-type: none"> Explain toy design to children Play!

TABLE 2. Goals and major activities of Bots for Tots sessions.

Participants then prototyped possible toy designs using paper, construction toys, and various craft supplies. Prototypes were encouraged to be completed rapidly and to highlight important design features or characteristics, rather than to perfectly capture the final design. After prototyping, students gained additional feedback from classmates before embarking on their final toy design. The last workshop session was used by the fourth-grade designers to build and complete their toys using wood, fabrics, 3-D printed plastics, pre-manufactured wheels, and other materials available in the fabrication lab. Completed toys were then delivered to the pre-K clients in a play session organized after the workshop.

IMPLEMENTATION ONE

The first implementation of the Bots for Tots project served as a successful proof of concept for leveraging alternate ways of knowing in the construction process. Designers expressed enthusiasm for building toys for their pre-K clients and many claimed this connection with the client was the highlight of the workshop. More girls than boys enrolled in the workshop and all girls interviewed after the workshop claimed they would prefer to continue building for others, rather than themselves, in future potential workshops (for a more complete description of the project and analysis of the first implementation see Holbert, 2016a).

Despite the successes of the first implementation, challenges encountered brought to light necessary tradeoffs in core interactions of the larger designed system. Particularly we encountered challenges in two key areas: the designer-client relationship and in the transitions from brainstorming, to prototyping, to constructing the final toy. In this section, we describe key choices made by the design team in the design of the Bots for Tots implementation and their outcomes. By revisiting these choices and the associated outcomes, we can extract core design tradeoffs that we then address in our next implementation described later in this paper.

Challenge 1: The Designer–Client Relationship

As presented earlier, a core feature of the Bots for Tots project is that participants build projects for others, rather than themselves. In this implementation, fourth-grade designers were tasked with building toys for pre-K children in their school. The pre-K children were chosen partly by design and partly by convenience. Initially, the first author had intended to build a relationship with a small daycare center located in the children’s neighborhood. However, while organizing details with the implementation school administrators, it was suggested that the student designers build for one of the school’s existing pre-K classes.

This was an attractive choice for two reasons. First, as the implementation school is a small urban elementary school, we thought it is plausible that the fourth-grade designers

#2)

- Pinkie-pie pony
jump, sing, walk, talk, ride
- Block-based phone
Blue
Makes sounds
- Red Race car w/ lasers
Monster Truck

mechanical	phone - old or New?
- outside Rubber	- buttons w/ stuff
- Big!	red lights for faces
- Hair w/ button interaction	- Big wheels
phone monster truck sounds	- windows
w/ speaker on cover	- button

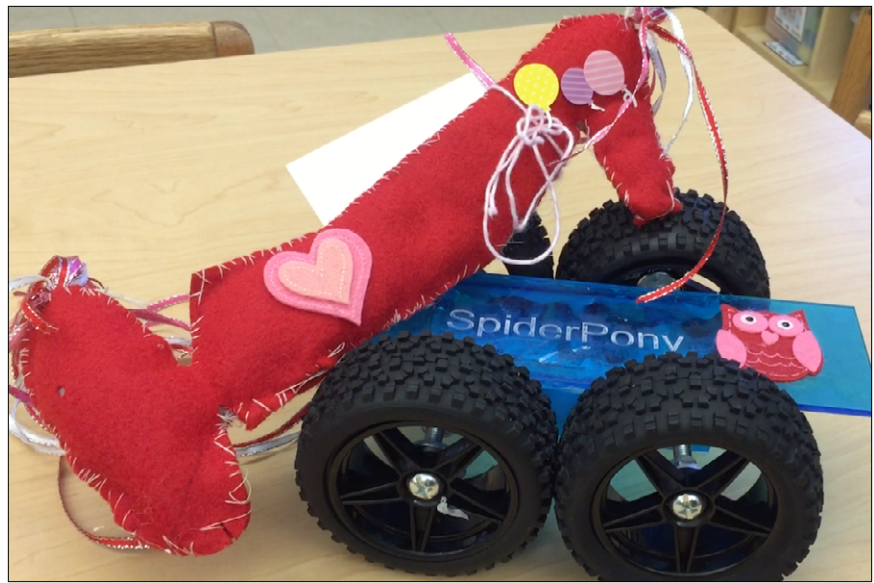


FIGURE 1. The designer-client interview resulted in an extensive and eclectic list of “dream toys” and features (left). Rather than just choosing one, the design teams took each request seriously resulting in highly unique and interesting toys that included not only each requested feature, but also personal flair such as the hearts, hair, and the voice recorder (the designers recorded themselves saying, “Hi! I’m Pinkie Pie!”) included inside the pony (right).

would have encountered the pre-K children in their building. Because both fourth-grade builders and pre-K clients share the same school halls, it seemed likely that builders would see their work as not only being for someone else, but also contributing to their school community. Furthermore, the age difference between clients and builders was large enough that we hoped the fourth-graders would see their efforts as “helping” rather than “gift giving.” More practically, because both designers and clients were located in the same school, teachers from each class (fourth grade and pre-K) were able to easily communicate and arrange meeting times and only a single school administrator needed to approve the project.

In early design meetings for the Bots for Tots project, we assumed a 1-to-1 designer-client relationship—that is each designer would have one client for which to build. We believed this matching would facilitate a personal connection between the builder and their dream toy client—that throughout the construction process the designer would consider the interests and desires of the client and be motivated to create something the client valued. In fact, this relationship was the core of our effort to tap into “connected knowing” (Belenky et al., 1986)—to frame making as a way of encountering and understanding others.

However, the partnering pre-K class had approximately 25 children! Rather than choose nine pre-K children to match with our nine designers, we split our fourth-grade designers into small teams of 2-3 children and assigned each team 5-6 pre-K clients. Designing for many clients, rather than one, meant that the designer was building for “the kids” rather than a particular child. While such design is not

uncommon—many service learning projects serve a wider community, rather than a particular individual (Swan et al., 2009)—we worried that young designers might need a more direct connection to the client to personalize the experience.

To encourage personal interactions between builders and clients, and to provide an opportunity for the pre-K children to express their interests to the fourth-graders, we facilitated a designer-client interview. While we had hoped this would be an opportunity for the two parties to discuss and share their interests in toys together, the larger group of pre-K clients meant the children simply listed off features of dream toys while the fourth-graders furiously recorded what was said. Likewise, during the build phase of the project, while the designers were highly motivated to include each listed dream toy feature in their constructions, they rarely referenced the client personally—completing the toy became more of an exciting challenge than a necessary component of building/sustaining a relationship. While designers and clients met again at the end of the project when the toys were delivered, the lack of additional contacts between the designers and clients likely exacerbated the impersonal nature of the client-builder relationship.

However, this design choice of a few builders to many clients led to an unexpected enhancement of the uniqueness and quality of the designed toys. Because each pre-K child had a very different idea of a dream toy, design teams began the project with a large list of toys that included highly diverse materials, features, and behaviors. For example, during the interview debriefing session, one design team told us their clients’ dream toys included a soft Pinkie Pie pony, a wooden phone that made sounds, and a monster truck

that shot lasers. Rather than simply choosing one of three toys described, or removing challenging or even impossible features, design teams took each request very seriously. This resulted in toy designs that were eclectic, unique, and challenging to design and build (see Figure 1).

Together these two outcomes suggest a design tradeoff around how one constructs the designer-client relationship. Specifically, a tradeoff between designer-client connectedness versus construction complexity. On the one hand, a 1-to-1 relationship might be more personal. The designer would know the client by name and would likely have greater knowledge about the desires and needs of the client. Such a relationship is more likely to meet the goal of facilitating connectedness at the heart of the Bots for Tots project and may appeal more directly to the values and goals of young girls. On the other hand, building for more than one client provided a larger and more complex design space that resulted in highly creative toys. It seems likely that the Pinkie Pie monster truck phone would not have been created had one client child only requested the pony, phone, or truck, rather than all three! These complex designs, in turn, provide additional opportunities for personalization and for designers of all kinds to infuse their construction with their own values and interests.

Challenge 2: Transitioning Between Stages of the Design Process

Our initial design of the Bots for Tots workshop utilized a relatively structured and common design process—namely the conceptualization of an idea to designing a prototype to crafting a final design. While we were quite flexible with the duration and particular activities that occurred in each phase, we hoped that including this small amount of structure would help the students make—and see—progress towards a final design.

Though it might seem like the design process is “gender neutral,” research suggests the materials used and the practices employed in making have the potential to implicitly frame the design process in gendered ways (Buechley & Perner-Wilson, 2012). For example, materials and tools can prime gender “norms” and as such, encourage boys or girls to take ownership (Kafai & Peppler, 2014). Consequently, as the research team moved participants through the design process, we intentionally encouraged a variety of materials (such as cloth, wood, acrylic) and monitored both participants and our own framing of activities. For example, if a boy began complaining a design was “too girly,” rather than contradict this assertion we would strengthen an alternative framing such as claiming, *“oh cool you added hearts to the pony! That looks really neat! What else could you add to it?”*

While carefully choosing materials that allow for diverse maker epistemologies is vital, which materials are made available when, impacts how novice makers progress through phases

of their design. Though all participants were comfortable and adept at brainstorming design ideas, progress became stalled when attempting to translate these ideas into useful and viable prototypes. The difficulty of the prototyping process seemed to be largely due to poor allocation of available time by the Bots for Tots team, a lack of participants’ prior knowledge around the purpose of prototyping, and fourth-grade designers choosing prototyping materials not suited to the task.

As can be seen in Table 2, the full workshop only consisted of three sessions (9 hours) devoted to the iterative design of the “dream toy.” This limited amount of time needed to be allocated thoughtfully to ensure participants successfully produced—on their own—a toy to be delivered to the pre-K clients. In this implementation, the brainstorming sessions—which occurred first as a team, then together as a group—proved highly productive resulting in many novel design proposals, valuable feedback and critique from classmates, and ideas that became shared and revised among different groups. Because these brainstorming and discussion activities seemed to be fruitful, in the moment of the workshop, we allowed them to continue for longer than initially planned, resulting in less time available for prototyping.

After ideating, we intended designers to begin prototyping—creating a preliminary version of their toy to test particular features or functionality or to gain insight into *how* to create a final and functional toy. Unfortunately, the fourth-grade designers were not familiar with the concept of prototyping. In particular, designers struggled to see how the prototyping process was sufficiently different from either brainstorming or creating the final product. Some designers had drawn the toy during the brainstorming process. How would additional sketches or constructions help them build the final toy? Others resisted the idea of making many quick prototypes instead insisting on the need to perfect drawings or prototype constructions.

Additionally, the materials made available to the fourth-graders for prototyping failed to provide a meaningful space for this exploration. In order to provide materials that might align more closely with feminine “craft,” rather than engineering or woodworking (Buechley & Perner-Wilson, 2012), and to streamline prototyping (without limiting its productivity), the team provided familiar craft and toy materials such as construction paper, pipe cleaners, cloth, Play-Doh, Legos, and Styrofoam. The young fourth-grade designers were particularly drawn to Play-Doh and Legos, two “toys” with which they likely had experience, but considering their age, were no longer part of their toy collection at home.

While designers enjoyed working with the Play-Doh and Legos, these explorations were not particularly productive for the crafting of the final design. Specifically, these materials provided little insight into the toy’s functionality or the

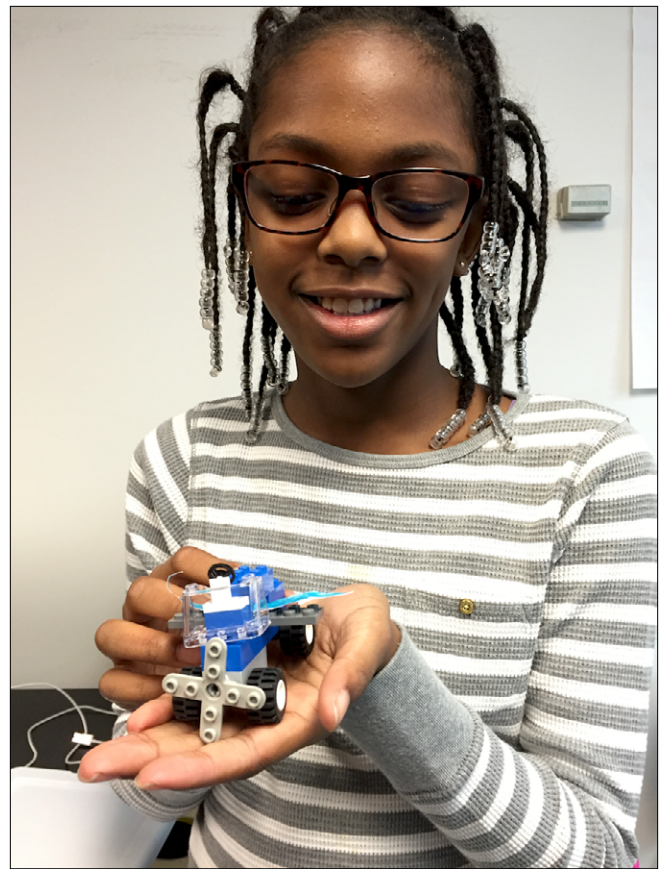


FIGURE 2. Prototyping materials such as Play-Doh and Legos, while interesting and enjoyable for the designers to use, provided few opportunities to explore and test the function and design of the final toy.

process one might go through to make the final product (see Figure 2). The malleability of Play-Doh would not match most materials proposed in the brainstorming session or their final design. Likewise, the ease of stacking Lego bricks obfuscates the considerations necessary for connecting rigid materials together. Moreover, the inclusion of certain materials, such as wheels in the Lego kit, may have privileged some design ideas over others leading to some similarities between teams in final designs.

These results suggest that when engaging young children in prototyping activities, one may face a tradeoff between material familiarity versus material relevance. Each material has its own particular affordances and constraints—these affordances and constraints should continually point designers towards likely successful constructions. Providing materials young children are familiar with should ensure they are comfortable picking up the materials and quickly working with them. However, this comfort may also prompt them to work with the material in the same way they might during play. Materials provided during the prototyping process should provide some consistency across the larger design—each material should provide additional insights into the process of creating the final product. Therefore, it

may be necessary to choose materials more “like” those that will be used in the final design, despite the additional time and cost likely incurred from using unfamiliar materials.

IMPLEMENTATION REVISIONS

While the initial Bots for Tots implementation resulted in a number of important insights around leveraging connect- edness to motivate young girls in making and engineering practices, implementation challenges prompted the research team to seek out additional partners in the design and implementation process. Eventually, the first and second author invited a local K-12 art and engineering teacher to join the design and implementation team. On her own, the teacher partner had conducted related projects and encountered similar challenges in her efforts and was enthusiastic about co-designing a new version of the Bots for Tots project that she could carry out in her school.

With the teacher partner, we revised the Bots for Tots design to address the challenges described earlier to fit the workshop into two new contexts (see Table 3). In the first, Bots for Tots activities occurred as a 1.5-hour weekly after-school maker club spanning a full semester. This afterschool

DESIGN CHALLENGES	PROS AND CONS FROM THE FIRST IMPLEMENTATION	SECOND ITERATION CHANGES	EXPECTED OUTCOMES
The designer-client relationship	PRO Since each pre-K client had many different dream toy ideas, building for a group of clients provided the fourth-grade designers a larger and more complex design space that resulted in highly creative and challenging designs.	<ul style="list-style-type: none"> In the private school location, design teams will build for clients that they have been paired up with in their school's "Big Sister" Program. This will result in a 1-to-1 client-designer ratio. For the public school, the few-to-many builder-client ratio will remain. 	<ul style="list-style-type: none"> The existing mentorship program will personalize the client—making the designer-client relationship a more central part of the design process. The Client Profile and additional interactions between designers and builders will generate a more consistent presence for the client during the construction process.
	CON The disproportional designer to client ratio meant designers saw the task as a challenge to incorporate all toy suggestions and did not seem to see the process as meaningfully developing a relationship with the client.	<ul style="list-style-type: none"> Both designer groups will create a Client Profile document, after the interview, that will provide a rich description of the client that they will refer to throughout toy construction. Likewise, both groups will meet with the client after they have built the prototype. 	
Transitioning between stages of the design process	PRO The designers were familiar and comfortable with using the provided craft and toy prototyping materials.	<ul style="list-style-type: none"> During the full design process material options will be limited to cardboard, foam, cloth, and wood. During the prototype phase, scraps will be used. Early activities will allow designers to encounter and practice techniques (such as making relief cuts) that will be useful throughout the design process. 	<ul style="list-style-type: none"> Because materials will be consistent throughout the design process, designers will be familiar with available materials. Variety in requested dream toys will ensure toys constructed continue to be diverse despite materials consistency.
	CON Because materials were different from those used in the final construction, prototypes did not provide additional insight into the process of making the final toy.	<ul style="list-style-type: none"> Students will be provided with a design process checklist that allows them to see where they are at in the design process and indicates progress as it is made. 	

TABLE 3. A summary of the design challenges identified after the first Bots for Tots implementation and the planned modifications for our second iteration

program occurred at the same public school where we completed our first iteration described earlier and was run by the second and first authors with additional graduate students as assistants. In addition, the Bots for Tots project is currently being implemented by our teacher partner as part of an engineering and design lab experience at an all-girls private school in a Northeastern U.S. suburb. Here the project is taking place over sixteen 40 minutes sessions occurring across one academic year. These two implementations allow us to explore the Bots for Tots design with nine and ten-year-old children that come from dramatically different communities, backgrounds, and school types. Based on the design tradeoffs noted earlier and in collaboration with our teacher partner, we have modified the Bots for Tots design

to ensure a high degree of toy design possibilities, close designer-client relationships, and more useful prototyping material choices.

As previously noted, there exists a possible tradeoff between designer-client connectedness versus construction complexity. More specifically, interviewing many clients provides a variety of design possibilities but may weaken the designer-client relationship at the heart of our efforts to privilege diverse epistemologies in making and engineering. In our second iteration, one context retains the few-to-many builder-client ration while the other uses a one-to-one ratio. We hope this design choice will allow us to more clearly identify the relationship between the client-builder ratio and depth of relationship and complexity of toy design.

At the private school, an existing “Big Sister” program—where each of the fourth-graders is assigned to mentor a younger grade one student—will form the designer-client dynamic. By connecting the Bots for Tots project with this existing mentorship program, we can leverage existing relationship-building opportunities between the designer and client that will occur in parallel to our project throughout the academic year.

At the public school, we are not able to leverage an existing mentorship program. Consequently, builders were once again connected with the pre-K class in their school. In this iteration, we intended to support this relationship with additional contact opportunities between design teams and clients. Specifically, rather than only see clients once at the beginning and again at the end of the project, designers will reconnect with clients throughout the design process.

At both contexts, designers will also be creating a *Client Profile* which includes the client’s photo, preferences, observations, and potential design considerations (gleaned from an interview with an early childhood expert) to guide them on personalizing their design. After designers complete their prototype, they will present the prototype to the clients to receive initial feedback and to observe how the clients interact with the prototype.

To smooth the brainstorm to prototype to final design transitions in this project iteration, we provided a design process checklist to builders so that they can see both where they are at in the design process as well as the progress that has been made. Furthermore, we have made a number of changes to the materials available in the prototyping stage. Particularly, we have constrained the material options for both the prototyping and final construction phases. Though it is efficient to use simple crafts and toy materials to make a prototype, the result from the first iteration suggests designers did not see the prototyping and final construction phases as sufficiently different.

In the second iteration, we restricted material choices to cardboard, foam, cloth, and wood throughout the design process to ensure there is an alignment between materials properties in all three stages of design. For the prototyping phase, scrap materials were provided, and designers were encouraged to make quick versions of their design so that the client can get an idea of how the final toy might look and function. This choice was made to encourage designers to focus on the construction and function of their design in each phase of the design process, as well as to allow techniques learned and used in early phases (such as how to make *relief cuts* in cardboard) to be useful in later design phases.

INITIAL REPORT ON THE SECOND IMPLEMENTATION

We have recently completed the implementation in the public school and are still in the process of our implementation in the private school. In the private school context, our goal to strengthen the designer and client relationship by leveraging an existing mentorship program and moving to a 1-to-1 ratio has shown positive results. Designers seem to be more aware of their client’s likes and dislikes, and the client is frequently discussed during design activities. Likewise, after the fourth-graders showed the first-graders their first toy prototypes, the fourth-graders incorporated this feedback as they began their final design.

In the public-school context, the planned builder-client relationship was forced to be abandoned mid-implementation when the culture of this urban school—with a large immigrant population—became threatened by changing national politics. While fourth-grade designers initially interviewed the pre-K population as planned, anxiety among participants about issues external to the project prompted the design team to reevaluate the project goals. Rather than build for the young children in their schools, the project team allowed designers to change their client midway through the project and to instead “build for someone you love to show them that you care.” Three designers chose to continue to build for the pre-K children, while others decided to build for close friends or family members. Even though our initial goal of building personal relationships between fourth-grade designers and Pre-K clients was shifted, designers continued to build something that would foster their relationships with the receivers. In all cases, the “client” was frequently mentioned during the construction process, and builders expressed pleasure at being able to build for someone they cared about.

To help students understand the transitions between stages in the design process, a design process checklist was included in a project folder. After each design stage, students checked off the recently completed stage.

Finally, restricting prototyping materials seems to have helped students construct productive prototypes. The private school condition utilized mostly cardboard in their prototypes and became comfortable with the idea that the prototype was just a step towards their final design. In the public-school context, students used cardboard, paper, and wooden scraps to prototype. While some designers required a nudge to go ahead and make a final product, most used their prototype to plan the design of their final toy.

CONCLUSION

In this paper, we have described two implementations of the Bots for Tots project and highlighted the ways in which reasonable and thoughtful design choices led to potentially

surprising challenges and tradeoffs. While having small teams of designers build toys for a larger number of clients resulted in highly complex and unique toy constructions, this grouping did not lead to a highly personal connection between designer and client. To overcome the lack of personal connection while retaining the complexity of toy design, in one implementation we leveraged an existing mentorship program and shifted to a 1-to-1 designer-client ratio. In another implementation, where the mentorship program was absent, we adapted the builder-client relationship to address the immediate needs of our fourth-grade builders. In both contexts, we employed a *client profile* tool to encourage designers to precisely describe clients, rather than think of them in the abstract. To amplify the value of the prototyping phase, in both implementations we constrained designers to only a few carefully chosen materials throughout the design process. This choice allowed designers to practice and refine skills developed throughout the design process and encouraged them to use the prototyping phase to focus on function rather than aesthetics.

While our goal is to encourage diverse participation in making and engineering, we have made efforts to ensure our resulting project design avoids unintentionally perpetuating a perception of engineering for boys versus engineering for girls. Giving children the opportunity to make and build artifacts of their choosing is a powerful way of encouraging them to explore engineering and design practices (Holbert, 2016b). However, by framing that process as a way of building connections with others, we hope to position construction as a powerful practice that requires a diversity of perspectives, values, and ways of knowing.

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