Examining Tensions Among Youth, Adults, and Curriculum as Co-Designers in 4-H STEM Learning Through Design Programs

Steven M. Worker, University of California, Davis, smworker@ucdavis.edu
Cynthia Carter Ching, University of California, Davis, ccching@ucdavis.edu

Abstract: This research study explored the relationships between three types of co-designers in 4-H STEM learning through design programs: youth participants, volunteer educators, and the curriculum. Each co-designer was involved in a process of planning and making in order to accomplish a goal to satisfy requirements subject to constraints. The enactment of the learning environment revealed tensions between the co-designers evidenced in participation structures (negotiated between the curriculum and educators); abstract versus concrete approaches (between the educators and youth); and tensions amongst youth peers while engaging in small group design teams (between curriculum and youth).

Keywords: design-based science learning, making & tinkering, pedagogy, volunteer educators

Introduction

There is a recognized need for learning environments that support open-ended problem solving and encourage young people's motivation to learn science, technology, engineering, and mathematics (STEM). Making and tinkering (M&T) have gained interest for their potential to spark, sustain, and deepen young people's participation in STEM (Gutwill, Hido & Sindorf, 2015). M&T practices, related to pedagogical strategies from project-based learning (PBL) (e.g., Barron et al., 1998), and design-based science learning, help foster problem solving, creativity, and ownership; support youth in developing dispositions as designers (and makers); and promote STEM learning (Kolodner et al., 2003; Roth, 2001). M&T and design-based science learning relies on pedagogical approaches that emphasize planning, designing, and making shareable artifacts through multiple iterations of design, testing, and failure (Mehalik, Doppelt, & Schunn, 2008). Through these iterative and emergent practices, participants ultimately create shareable artifacts serving as external representations of knowledge (Puente, van Eijck, & Jochems, 2012). Artifacts become concrete objects of talk available for critique and reflection (Roth, 1996). Research on instructional approaches integrating engineering *design* with science *inquiry* originated from work in schools (e.g., Learning-by-Design, Kolodner et al., 2003) and is related to M&T approaches often situated in out-of-school contexts (e.g., Honey & Kanter, 2013).

Research has often described idealized potential in M&T environments; for example, looking at leveling power dynamics between students and teachers (Schwartz, DiGiacomo, & Gutiérrez, 2015) or highlighting the potential of M&T to be more responsive to students' needs and thus, having potential to address inequity in STEM education (Vossoughi, Escude, Kong, & Hooper, 2013). There has been less research on pedagogy, and even less on the role of the curriculum (the sequence of facilitated activities), in shaping the learning environment for productive youth learning. One fruitful line of inquiry may be to study these spaces "in the wild," that is, in settings not organized or implemented by the researcher or by an experienced teacher. The dynamic nature of a learning environment, as well as the negotiations between actors, is messy, and greatly influences affordances for participation and learning. As such, multiple actors and artifacts shape the emergent nature of activities and sequences in the learning environment. We define "designer" as an actor in the learning environment exerting a substantial influence over the learning process: youth participants, educator, and curriculum.

M&T spaces abound in out-of-school time (OST). OST has been advanced as a space that nurtures youth interest, ownership, and learning of STEM (NRC, 2009). Many OST programs are organized by adult volunteers, offering youth voluntary participation and choice, and engaging youth over an extended period (McLaughlin, 2000). These volunteer educators often lack competence or confidence in implementing STEM education and must respond to structural constraints (e.g., voluntary participation, frequent absences, wide range of ages, organizational priorities). OST may help shed light on pedagogy employed thus clarifying tensions among major co-designers as the learning environment is co-constructed and how that, in turn, expands and/or limits opportunities for youth to learn and develop.

Theoretical points of reference

We employed sociocultural theory to make meaning of data and understand participants' values and meanings they ascribed to tools, practices, and expectations. Sociocultural theory places culture as a core concept in learning and posits that learning, development, and culture have a complex, intertwined relationship that contributes to a child's capacity and agency to function in the world (Rogoff, 2003). Sociocultural perspectives typically employ *participation* as a metaphor to describe their intertwined nature of learning and development (Sfard, 1998). Our research, using a sociocultural approach (e.g., Lave & Wenger, 1991), focused on instances signaling deepening forms of participation and indicators of learning broader than standard-based definitions.

Methods

The purpose of the study was to describe the co-construction of learning environments by volunteer educators and youth in a naturalistic setting. The research questions addressed by this study were:

1. What are the pedagogical strategies employed by volunteer educators?
2. How do these teaching strategies influence youth (i) engagement in design practices, (ii) learning of STEM, (iii) strengthening tool competencies, (iv) manifestations of learning dispositions, and (v) development of psychological ownership?

By inquiring into these research questions, we sought to identify places of tension which revealed divergent goals and expectations between participants.

Research context

The research context was three 4-H educational robotics programs, emphasizing STEM education, organized by adult volunteer educators in Alameda, Santa Clara, and Solano Counties, California. The decentralized nature of the 4-H organization, and its reliance on volunteer educators, affords educators freedom and authority to design their own program goals, lesson plans, and make adjustments throughout the year. There are few educational standards for 4-H educational programming, although there are curricula available to aid volunteers in sequencing content and facilitating with experiential pedagogy. In this study, educators employed the *4-H Junk Drawer Robotics (JDR)* curriculum (Mahacek, Worker, & Mahacek, 2011). This written curriculum targeted middle school youth with a sequence of "messing about" science inquiry activities followed by engineering design challenges. Design activities invited youth to design, build, and test artifacts using common items (e.g., paperclips, rubber bands, craft sticks, tubing and syringes). The design challenges were framed in a non-competitive atmosphere encouraging youth to experiment and tinker with multiple solution pathways. While the domain was robotics, the curriculum has more in common with tinkering with its emphasis on learning through messing about with common materials. There were no pre-packaged kits (e.g., VEX, LEGO) and no computer programming.

Data collection and analyses

This research project relied on naturalist and qualitative multiple-case study methodology relying on participant observations and video clips, interviews with educators (Seidman, 2013), and focus groups with youth (Krueger & Casey, 2015). Data collection took place between 2014-2015 at three sites: Santa Clara, male educator and seven youth (three male, four female; between 11-16 years old) which met two-hours twice per month (six meetings); Solano, three educators (one male, two female) and eight youth (all male, between 10-12 years old) which met for an hour once per month (7 meetings); and Alameda, male educator and seven youth (3 male, 4 female; between 9-15 years old) which met for an hour once per month (six meetings). The final data corpus consisted of 17 field notes (with 139 minutes of video and 846 photographs), seven educator interviews (5 individuals; 273 minutes), three youth focus groups and two individual interviews (130 minutes). Data analyses was oriented by an inductive and comparative process beginning during field work in the form of analytical notes where we noted questions, emerging patterns, and themes (Merriam & Tisdell, 2016). Field notes were delimited using markers to segment data for deeper analysis. Analysis of focus group and interview data followed a systematic process of abstraction, delineating the transcripts using the same markers. This process of analyzing field notes separately from the individual data supported triangulation as we sought to identity concurrence and inconsistencies in educator's narrative from participant observations.

Findings

The unfolding of these 4-H learning environments was a complex progression involving interaction, negotiation, and contestation between three types of co-designers: the youth participants, the volunteer educator, and the curriculum. We identified these as designers because each was involved in a process of planning and making in order to accomplish a goal to satisfy requirements subject to constraints (the definition of design).

Designer: Youth participants. Youth-as-designers, in a traditional sense, saw them designing, building, and testing physical artifacts where they learned through an iterative design process (as intended by the curriculum). Youth were functioning in the role argued for by DiGiacomo and Gutiérrez (2014): "children should be the designers, rather than consumer, of the artifacts with which they interact" (p. 729). The learning environment, as influenced by the other two co-designers, afforded opportunities for learning STEM content; strengthening tool competency; manifest learning dispositions: resilience, reciprocity, and playfulness (three important learning dispositions outlined by Carr & Claxton, 2002); and developing psychological ownership. Youth were also autonomous agents in the learning environment, where they decided with whom and how to interact with the materials, tools, peers, and adult educators while working in teams to design, construct, test, and redesign an artifact to fulfill pre-specified design requirements; i.e., some youth decided not to return in future meetings while others decided how they participated (e.g., "primary building", "peripheral member").

Designer: Adult volunteer educators. Educators were also designers, though their design goals differed from youth – they were designers of the learning environment with a goal to support youth learning. Educators worked within structural constraints, such as fluctuating attendance and the need to make activities fun, along with their own values and expectations for STEM education. The design work of the educator took place before and during the meetings. The practices of educators included selecting and adapting curriculum activities; facilitating an activity including allocating time for participation structures; framing and orienting youth to concepts and practices through varying pedagogical techniques- information transfer, autonomy support, metacognitive support, emotional coaching, and running interference. The participation structures and associated pedagogical techniques served to open and/or close avenues for youth to learn.

Designer: The curriculum. The curriculum was also a co-designer in the learning environment, with its interactions taking place both in real time by shaping interactions through its youth notebook and facilitator guide and through remote collaboration with the curriculum developer. The developer designed an intentional sequence of activities, including suggested participation structures and pedagogical techniques (learning activities, group sharing and reflection, and design & build), to generate expected learning goals for youth. The design work of the curriculum developer included responding to future ideas of activity requirements and constraints, completed long before the educator and youth came together. This idea has theoretical basis; the curriculum, a social and historical object, was a cultural tool "designed to foster collaboration and interaction in thinking among people participating in shared activity at a distance" (Rogoff, 2003, p. 274).

There were points of alignment between the design work of the three co-designers as well as areas of tension. In this paper, we share three examples that illuminate areas of tension between the co-designers: educators and curriculum; educators and youth; and curriculum and youth.

Participation structures: Tensions between the curriculum and educator

The type and sequence of activities, as well as the pedagogy, afford and/or constrain youth participation and learning. Youth were engaged in open-ended design practices, with opportunities for problem solving through failure and persistence (i.e., to manifest resiliency, playfulness, and reciprocity) are important in supporting the development of ownership, tool competency, and STEM content. Two co-designers were concerned with the type and sequence of activities to promote youth learning – the curriculum and the educator - however, at times, there were tensions between their solution pathways.

We employed participation structures as an analytical lens, in line with sociocultural theory, to describe patterns of activity, the allocation of time, and corresponding interactional norms (see Jordan & Henderson, 1995). From the data analysis, we identified six discrete participation structures: *lecture* (educator-led explanation of science or engineering ideas), *demonstration* (educator-led demonstration of a concept, tool, device, or artifact), *learning activity* (an educational activity facilitated by the adult with youth having "hands-on" time with manipulatives), *group sharing and reflection* (educator-facilitated group time where youth shared their artifact and received feedback from the adult and peers), *scripted build* (youth followed the educator's instructions on assembling an artifact), and *design and build* (time for youth to design and build an artifact).

We calculated the amount of time spent in each participation structure over time by site (See Figure 1) using timestamped field notes. The allocation of time varied by site with Solano dedicating the most time (81%) to design and build, Santa Clara with the next most frequent design and build (46%), and Alameda with the least time in design and build (12%) but more time for scripted build (31%) and learning activities (33%). Only Alameda offered scripted builds and allocated the most time in lecture (22%). Santa Clara spent more time in group sharing and reflection (22%) than any other site. There was a stark contrast between sites in the allocation of time (e.g., Solano with much more design and build and Alameda with significantly less).

The tension was evident in the use of participation structures themselves. The *4-H Junk Drawer Robotics* curriculum only included three of the six participation structures – *learning activity*, *sharing and reflection*, and *design and build* – and did not include instructions for or recommend the *lecture*, *demonstration*, or *scripted build*. These three participation structures originated from the educators themselves. Interviews revealed that educators used the curriculum primarily as a legitimizer that this could be an appropriate 4-H program but then during the project as one of many resources to structure and sequence the learning activities.

However, all educators went “off book” for a variety of reasons, resulting in variation in how youth participated. At the same time, educators were dealing with pragmatic and structural constraints for which the curriculum did not attend. Educators were often adapting to structural constraints such as voluntary participation, by ensuring meetings were fun. The 4-H program, like many other community-based youth programs, is voluntary where youth have freedom and flexibility to participate.

> Sawyer (Alameda): Because this still has to be fun. As much as I love teaching engineering and being exciting about this stuff we’re doing, if it’s not fun the kids won’t be back. I’m not there to entertain them per say. [The project] has to be moving and keep going. If we are spending a lot of time reading books or not doing anything, then the kids will get bored and they won’t come back to the next class. (Interview, 10/13/2014)

Sawyer recognized that while he wanted youth to learn engineering, he had to ensure meetings were fun for the youth, because if they were not, youth may not return. The nature and definition of “fun” was seen as offering hands-on activities. The term hands-on, however, was utilized in different ways by educators. One meaning focused on tinkering in service of reinforcing engineering learning while another meaning emphasized tinkering as a learning goal in itself. This reflects another reason for divergence between curriculum and educators, that the educator’s goals, interests, and values shaped their instructional practice with some spending more time in activities they thought valuable and in which they had an interest.

> Robin (Solano): I’m a hands-on learner. … some of today’s youth are the same way. They’re not – they have to do it to physically learn it, and that’s how I am. So I like to tinker and play with stuff. (Interview, 6/22/2015)

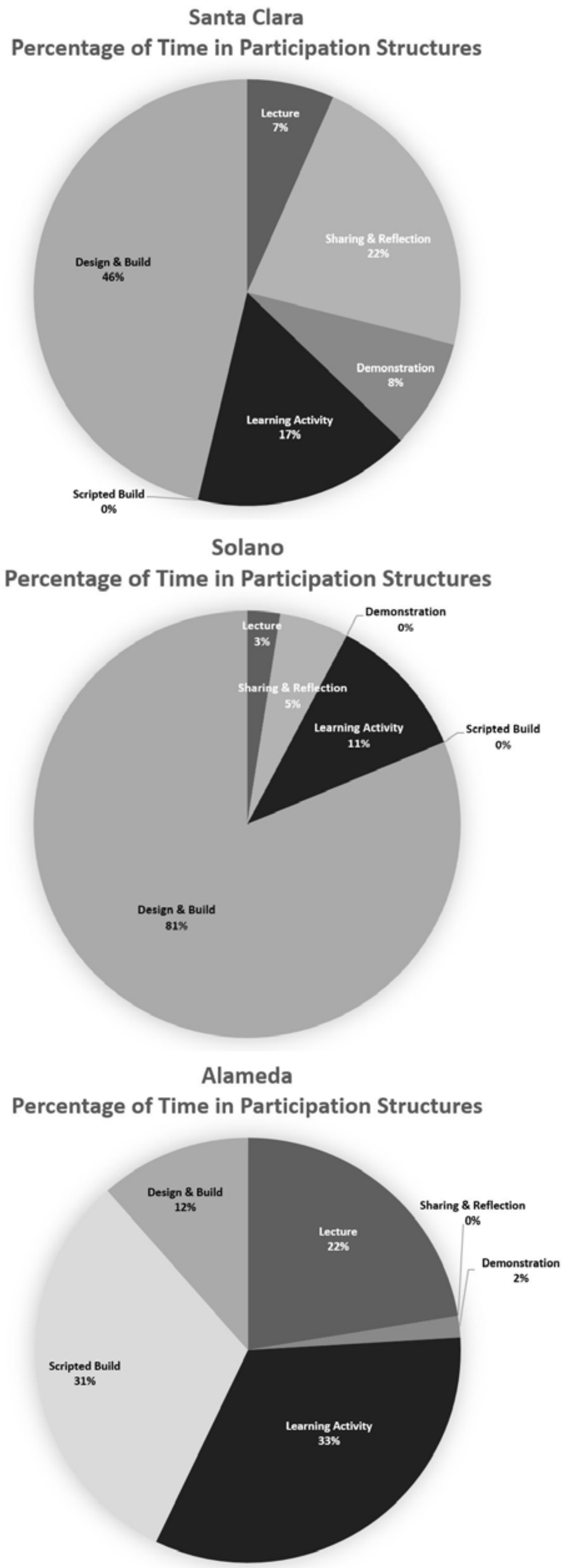

Figure 1. Time in participation structures by site.

Robin stated that she valued hands-on design experience for its value in the service of tinkering. Further discussion with Robin revealed connections between her valuing hands-on learning and the goals she had for learning: having youth learn to be creative and developing a tinker mindset. This value was seen in the allocation of time at the Solano site in *design and build* (81%), which was much more time than the other two sites.

Educators' competence and confidence in engineering were related to their approach structuring the sessions with an indication of an inverse relationship where competence and confidence in engineering were inversely related to pedagogies emphasizing metacognition and autonomy support and more information transfer approaches. In other words, educators who identified as professional engineers, who had been enculturated to professional engineering fields, were observed employing more information transfer pedagogical strategies.

> Eugene (Santa Clara): I wanted to teach them something specific ... So it just naturally evolved and at the last meeting, I think the feedback from the kids wanted less talking, which is ok. We'll try to accommodate that. But I think there was a lot of learning that happened through that process. (Interview, 4/2/2014)

Further in the interview, Eugene reiterated his belief that youth needed engineering fundamentals, information, and concepts before they could successfully start building. He believed this approach produced better learning outcomes, but he recognized youth preference for more hands-on open build time.

The significance of this discussion is in how participation structures afford and/or constrain youth participation and learning. Data revealed that three participation structures – *lecture*, *demonstration*, and *scripted build* – primarily afforded STEM content learning and tool competency. The other three participation structures – *learning activity*, *sharing and reflection*, and *design & build* – afforded a broader range of learning. *Learning activities* were not about engaging in design practices or building, but rather, becoming familiar with a STEM concept though youth were observed manifesting a playful disposition, showing creative behavior in response to their peers and the educator. *Group sharing and reflection* was always in relation to something youth had built, and hence, served as evidence that youth had engaged in design practices, improved their tool competency, manifested dispositions (resilience, reciprocity, and/or playfulness), and developed a sense of psychological ownership. *Scripted build* was focused on youth following instructions to build the same artifact. Youth had opportunities to use tools - soldering irons, heat guns, and multimeters - to make something. An important distinction in tool competency between *design & build* and *scripted build* was that in the former, youth had freedom to choose when to use a particular tool, whereas in the later, there was an ordered sequence. We often observed youth using tools that we thought were not best suited for a material modification, and yet, this autonomy afforded youth opportunities to grow their tool competency, by using tools, learning how tools functioned, what their limitations were, all in the service of building a shareable artifact. During *design and build*, youth engaged in design practices where they generated ideas to meet the challenge (design) and then built and tested prototypes (build). This process afforded opportunities for youth to manifest resilience as they encountered challenges and failures, to contribute to each other (reciprocity), and be playful and experimental. Youth had opportunities to strengthen their tool competency and develop a sense of psychological ownership for their artifact.

Abstract or concrete approaches: Tensions between educator and youth

There has been longstanding friction between the developmental value of abstract/formal reasoning compared to concrete approaches (described as "bricolage" by Turkle & Papert, 1990). Those advancing making and tinkering commonly maintain the value of hands-on tinkering to promote creativity and motivation. M&T may contribute to a more supportive environment to integrate thinking and acting where participants make, explore, test, build, and redesign through cycles of iteration. However, school-based norms often find themselves weaved into out-of-school environments, and many of the educators in this study espoused abstract learning goals including the fundamentals of engineering, writing specifications (engineering notebooks), and transferring these principles to other areas in their lives. Across the study sites, I observed tension between educators' emphasis on learning activities to engage in more formal planning while youth preferred *thinkering* – a metaphor used by Roth (1996) to describe the "integral activity that had mental, material, practical, and social aspects" (p. 147).

The tension was observed through the educator's learning goals and emphasis on the planning aspects of design while youth expressed their desire for "less talking" and more "building." For example, youth were asked to draw their designs on paper before beginning to build with the materials. This approach represented both the curriculum and educators' values of abstract thinking, namely, dividing the process into discrete components: first youth develop a representation of the artifact and then they handle materials and use tools to build the artifact. For example, at the Solano site, youth were asked to draw, individually, a gripper to be added to their group's arm. During group sharing, three youth had drawn devices using materials not available; one with "Dr. Octopus arms", another with tongs to pick up the world, and a third with large metal claws. Two youth drew and shared designs incorporating with materials at-hand; one with a gripper using hydraulics while another with plate-like grippers. These two youth recognized constraints of materials which demonstrated awareness of design realities and material properties. The excerpts highlight a shortcoming of abstract representation, namely, that when asked to draw a design, these youth engaged in playful and creative thinking – which does have a place in learning – not limited by the properties of materials. However, their designs were not feasible or indicative of materials constraints. Furthermore, the process of developing a representation did not attend to the types of tools or the processes youth would need in order to complete their artifact. Had youth been able to use materials to think and act, their designs would have been naturally self-limiting due to the constraints of the materials' properties themselves. Youth engaging in tinkering with materials are naturally constrained by the materials and tools. Abstract representations can be fanciful and limitless, cultivating creativity, but tinkering with materials can be frustrating, promoting resiliency and persistence. In the context of a program emphasizing design practices, important learning concepts include constraints of materials which require analyzing trade-offs in design.

In focus groups, youth expressed a preference for tinkering and building. One youth summed his feelings for his least favorite activities: when "we did not get to build stuff" (Gordon in Alameda, 5-3-2015) In Santa Clara, youth preferred more build projects and less of the educator lecturing and demonstrating. One youth provided a response to the educator's question around "what would make this project more fun?"

Jason (Youth):	Make your things at the beginning a little more shorter.
Eugene (Educator):	Make my what things?
Jason (Youth):	The presentations, since I'm pretty sure some of us were getting bored. …
Eugene (Educator):	Ok. Yep, I agree. I agree. I felt sort of like that. I like at the end you spent a lot of time building. But I think in the very beginning if I didn't talk a lot it would be difficult for you, in my mind, to start working. Now, the last few sessions, I think we did a lot more building. And I think that was a lot of fun, I agree. Absolutely.

(Field Note Santa Clara, 3/26/2015)

Tensions were evident when educators front loaded content (like Eugene in the excerpt) or had youth draw designs before building- all around having youth work it out in their heads before they did it with their hands. Educators' learning goals were a factor in allocation of time between participation structures and their pedagogical strategies. There was a contrast between more information transfer oriented participation structures (*lecture*, *demonstration*) and those affording more metacognitive and autonomy functions. The former was seen as "talking" and mostly focused on abstract concepts while the later involved youth tinkering and build time. Valuing abstract reasoning in this space served to reinforce school-based norms, something that may limit opportunities for the very thing those advocating for M&T value- creativity, open-ended problem solving, and shifting of power balances between teachers and students.

A primary builder: Tensions between youth and the curriculum

Providing opportunities for collaborative work has become something of a standard for project-based learning utilizing a peer-support social organization model. This is often rationalized as a reflection of professional practice (Puente et al., 2012), providing peer scaffolding (Rogoff, 2003), or tapping into other benefits of collaborative learning (Cohen, 1994), yet success has been found to depend on the quality of interaction (Barron, 2003). The *Junk Drawer Robotics* curriculum advanced small group learning wherein youth would work in small groups to share, design, and build together. Curriculum activities instructed educators to split youth into groups of two to four. The social organization recommended by the curriculum was implemented by educators at two of the three sites, however, the educator at Santa Clara had youth build individual projects.

Teamwork, advanced by the curriculum, and facilitated by the educator (at least at two sites), revealed another tension, evident when one youth spent more hands-on time with the artifact than their team members, making more modifications to the artifact without asking or explaining to team members, issuing instructions to team members, and acting as the spokesperson when sharing the team's artifact. This occurred even though educators often verbalized their values: "You guys need to work as a team" (Joyce in Solano, 11/5/2014).

We labeled a young person fulfilling this informal role the "primary builder" to designate the youth who controlled the team's artifact. The primary builder did not attempt to include other team members and was not receptive to their ideas; in essence, the primary builder controlled the artifact and excluded teammates. There were conflicts between group members, often disagreements around design decisions, especially in the earlier meetings, however, as meetings progressed, and a primary builder was established, there were fewer arguments evident, almost as though the primary builder had established themselves as the boss. The primary builder phenomenon was not without frustration on the part of other members. This example from the last meeting of the project illustrates discontent for not being able to be more involved.

Steven (Researcher):	What was your least favorite activity?
Greg (Youth):	It might be the fact that I was just sitting around just handing supplies to Jack while he built the whole thing. He basically built the whole thing. I just fastened everything ...
Steven (Researcher):	Tell me more about that.
Greg (Youth):	He was the mastermind of the whole thing. … So he gets most of the credit for that. About maybe 75 percent credit for that.

(Focus Group Solano, 4/1/2015)

As quoted above, Greg's least favorite experience was not being as involved in the building of the artifact as he recognized that Jack did most of the work. This experience was echoed by other youth who did not serve as a primary builder in their respective groups. These other group members were often not included in significant design practices, yet continued to serve in legitimate, though peripheral, roles. For example, many of these peripheral members created a flag which may have been a way of signaling "this is mine, I contributed" even when the youth did not contribute to design of the primary artifact.

This is an insight into the tension evident between the curriculum's emphasis on collaborative work and this not happening in practice, even with prompting (though not scaffolding) from the educator. The hazard of a primary builder is in how it limits opportunities for other youth to engage in design practices, use tools, manifest dispositions, and develop ownership. Peripheral team members were not able to engage as fully in the design process, did not tinker as often, did not think through design decisions as often, and did not use as many tools. This certainly has consequences for the quality of learning afforded to peripheral team members. It also has disadvantages to the primary builder. Verbalizing design ideas with teammates facilitates communication, including conflicts, disagreements, and arguments, all of which may contribute to the generation of new perspectives and ideas.

Conclusions and implications

A particularly salient point illuminated by this paper is in how OST volunteer educators have to adapt to the structural constraints of their respective settings. In interviews, educators spoke frequently regarding voluntary participation in relation to their pedagogical practice, that is, having to consider that youth can "vote with their feet" (voluntary participation). Educators' recognized that while they wanted youth to learn engineering principles, they had to ensure meetings were fun, because if they were not, youth may not return. The nature and definition of *fun* was understood as offering hands-on activities; one educator was very emphatic – Sawyer: "Flat out, hands on." (Interview, Alameda, 10/13/2014). Maintaining youth engagement and interest was often seen as so crucial, that volunteer educators felt they had to make compromises in order to maintain the fun. A consequence are unplanned activities, like the Alameda *scripted build*, that preserved hands-on activities but at the expense of affording youth agency and opportunities to engage in design practices, strengthen tool competencies, exhibit resiliency, or improve feelings of ownership. These adaptations can also result in new and innovative activities, like a full-sized teeter-totter in Alameda. This activity could not have been included in a curriculum because of expense, technical knowledge to assemble, and space constraints, yet the educator's interest and passion prevailed, coupled with the flexibility provided by institutional context, and youth got to experience the concept of lever (and pivot point, fulcrum, torque) through a novel whole-body experience. In summary, in OST spaces, volunteer educators bring with them their own notions about effective teaching, their own interest and values, and through their pedagogical strategies, afford and constrain opportunities for youth to participate and learn.

M&T spaces, emphasizing design practices, may indeed hold idealized potential to "engender new types of participation structures where students and teachers can learn and become in practice, together" (DiGiacomo & Gutiérrez, 2014, p. 736). The results of this study, however, show how complex and problematic the leveling of power between teacher (and curriculum) and students may be in OST environments. Redefining relationships may be possible, but it is not necessarily a virtue of M&T in and of itself, but rather in the complex relationships and dynamic negotiations between co-designers. Studying teaching practices "in the wild," in settings facilitated by educators with varying competencies, illuminated the complex negotiations between three co-designers – youth, volunteer educators, and the curriculum – which explored questions about who can and does decide the nature of the activity structures.

This study contributes to our growing understanding of STEM learning through design in out-of-school time by illuminating tensions among major co-designers and how that, in turn, afforded and/or constrained opportunities for youth to learn and develop. These co-actors were not without conflict, thus suggesting that these spaces and pedagogies do not exemplify STEM learning on their own, but neither do they preclude practices that deepen young people's interest and motivation for STEM learning.

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