Tinkering, Learning & Equity in the After-School Setting

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ABSTRACT

In this paper, we attempt to bring equity to the fore within discussions of learning in tinkering and making. Drawing on ethnographic data collected over the last year and a half, we argue that equity lies in the *how* of teaching and learning: specific ways of designing making environments, using pedagogical language, integrating students' cultural and intellectual histories, and expanding the meaning and purposes of STEM learning. We build this argument by sharing some of the design principles, interactions and practices that constitute the Afterschool Tinkering Program – a partnership between the SF Exploratorium and San Francisco Boys and Girls Clubs. We focus on defining and elucidating a *situated* understanding of equity in order to: 1) identify the specific tensions and possibilities we see within discourses of tinkering/making for educational practice 2) develop new ways of perceiving and supporting children's learning in making environments where equity is a central organizing principle 3) present a preliminary analysis of the kinds of learning we have documented in the After-School Tinkering Program, and consider what these examples offer for helping re-imagine education *as it could be* (Boal, 1995).

Keywords

Tinkering, Learning, Equity, Pedagogy, After-School Settings, Ethnography

INTRODUCTION

Tinkering and making have recently been taken up by educators as potentially rich intellectual activities, and as tools for broadening engagement in a variety of disciplines, including STEM (science, technology, engineering and math), literacy and the arts. Organizing educational experiences around tinkering often involves a radical emphasis on the *process* of creating and learning, and an effort to bring skills and concepts alive in the context of children's creative pursuits. These efforts draw upon a range of progressive educational traditions and take an interdisciplinary approach to STEM learning that privileges problem-solving and iteration, grounding scientific inquiry in the developmentally rich context of invention, art and play.

The recent up swell of enthusiasm and investment in tinkering/making signals both a need and hope for re-imagining the educational status quo, particularly in STEM education (Honey & Kanter, 2013). In response to a technocratic and often corporate approach to education characterized by standardization, high-stakes testing and the narrowing of school curriculum (Baker, et. al., 2010; Rose, 2010), educators in a range of settings have been experimenting with alternative pedagogical approaches. These include interweaving the scientific and the everyday, "thinking with our hands," and supporting young people to participate in the real work of scientists, artists and engineers.

Yet, within this growing "maker movement," we have also noticed a dearth of public discussion around issues of culture and equity, leading to some fundamental tensions and missed opportunities. Though this movement is responding, in part, to the standardization and narrowing of school curriculum, the question of how to best serve students that bear the brunt of these policies – working class students and students of color – is not often at the center of the public conversation (Harvard Civil Rights Project, 2006). When equity is discussed, it tends to be in terms of "broadening access" to high quality STEM learning, which can result in externally rather than locally defined initiatives and unexamined definitions of what counts as science. While supportive of these intentions, we seek to push the conversation to consider the pedagogical *how* of creating environments that are deeply responsive to students' needs and strengths, and rooted in a critical, historical analysis of educational and social inequity. We bring these tensions into relief in order to elaborate on the possibilities for the democratic (i.e., distributing resources and creatively adapting the experience of tinkering/making) and pedagogical (i.e. designing learning with equity in mind) future of making.

In our own work as educators and researchers, equity has been a central concern and organizing principle. The focal setting of this paper, the Exploratorium After-School Tinkering Program, collaborates with Boys and Girls Clubs in San Francisco to develop a sustained tinkering curriculum focused on interdisciplinary forms of STEM learning. The program predominantly serves African American, Latino/a and Asian American youth (K-12) from communities with restricted access to educational and economic opportunities. Building on the work of the Exploratorium's Tinkering Studio, the After-school Tinkering program aims to develop teaching and learning practices that cultivate "tinkering dispositions" and shared experiences of intellectual possibility. In line with the philosophies of the Boys and Girls Clubs, learning is also grounded in youth development and play. Adults, teens and children meet in a workshop setting to design and co-create artifacts such as scribbling machines, stop-motion animation films, shadow plays, wooden pinball machines and musical instruments.

In this piece, we attempt to bring equity to the fore within discussions of learning in tinkering/making by drawing attention to the design principles, interactions and practices that constitute the After-School Tinkering settings. Throughout the process of developing and studying these settings, we have returned time and again to the idea that equity is not only a matter of broadening access to high quality STEM learning experiences. Rather, we argue that equity lies in the *how* of teaching and learning: specific ways of designing the learning environment, using pedagogical language, incorporating students' cultural and intellectual histories, and expanding the meaning and purposes of STEM learning. In this spirit, we look closely at the After-School setting and ask:

I. How are tinkering environments designed to support equity?

- **a.** What features of the pedagogical environment nurture participants' development of new ideas, practices and relationships?
- **b.** When and how do we see learning?

We respond to these questions by looking at key characteristics of pedagogical practice in relation to shifts in talk, interactions, artifacts and relationships among participants. We begin with a discussion of method, describing our approach to ethnographic research as well as the relationships among researchers and practitioners. We then unpack key terms, offering a situated definition of tinkering that grows from our data and our experiences working in the after-school settings. We then identify four central dimensions of equity-oriented practice in the After-School Tinkering Program and offer preliminary examples of what these elements look like in practice. We conclude by discussing the implications of these findings for teaching and learning.

METHODS

Understanding trajectories of learning – how particular skills, understandings and practices develop and endure – requires detailed descriptions of the educational setting, including the specific practices and dispositions emphasized by educators (Erickson & Gutiérrez, 2002; Matusov, 1998). This paper draws on ethnographic methods (participant observation, audio-video analysis, photographic documentation of children's artifacts and writing, interviews with children, parents and program staff, and examination of tinkering artifacts over time) to offer a preliminary description of teaching and learning in the after-school program.

Ethnographic research emphasizes the immediate and local meanings of actions as defined from the actors' points of view. Most broadly, this type of research asks: What are people doing here, specifically? What do these happenings mean to the people engaged in them? (Erickson, 1986). This type of research is essential to determining program effects and amplifying successful pedagogical practices. According to Erickson and Gutiérrez (2002), "A logically and empirically prior question to "Did it work?" is "What was the 'it'?"—"What was the 'treatment' as actually delivered?"- a question best answered by qualitative research. Developing "thick descriptions" (Geertz, 1973) of pedagogical practice (the "what" and "how" of teaching and learning) also generates concrete resources for educators by providing pedagogical strategies and models that can be adapted to serve local practices.

Within this framework, our research utilizes social interactional analysis of educational discourse (Bremme & Erickson, 1977; Cazden, 2001). Studying educational discourse within after-school programs organized around tinkering provides a substantive window into the kinds of pedagogical practices and forms of learning specified in our research questions. Fine-grained analysis of talk and interaction allows us to study how participants, over time, take on the roles and discourse forms that are valued in problem posing and solving within the after-school setting (O'Conner & Michaels, 1996). In the examples that follow, we **bold** portions of the transcripts that we wish to highlight for analysis.

Finally, in line with collaborative action research (Erickson, 2006), formative interventions (Engeström, 2011), and social design experiments (Gutiérrez & Vossoughi, 2010), our research is deeply embedded in program design and implementation. Researchers and educators collaboratively design pedagogical environments and reflect on the kinds of shifts that emerge among participants in the after-school settings. In practice, this process of co-design involves educators serving as contributing members of the research team, and researchers participating as co-designers of curriculum and pedagogy. The director and lead educator of the After-School Tinkering Program therefore played a central role in co-designing research questions, observational and interview protocols, codes and analyses.

TINKERING & MAKING

> Making is the practice of weaving, in which practitioners bind their own pathways or lines of becoming into the texture of material flows comprising the lifeworld. Rather than reading creativity 'backwards,' from a finished object to an initial intention in the mind of an agent, this entails reading it forwards, in an ongoing generative moment that is at one iterant, improvisatory and rhythmic (Ingold, 2000, p. 91).

In developing and studying educational environments organized around tinkering and making, we are fundamentally interested in the relationship between children's "lines of becoming" and the iterant and improvisatory process of creation. We therefore seek to understand the kinds of conversations - with materials, tools, ideas, others, and the self – that open up when learning is organized in ways that privilege the 'ongoing, generative' process of thinking and making. In this section, we offer an elaborated definition of tinkering, grounded in our observations and participation in the after-school settings. These are working definitions that emerge out of our particular context. In other words, we do not intend to define tinkering or making writ large. In recognizing these practices as fundamentally human, historical and cross-cultural, we appreciate the multiplicity of forms they can take - and seek to add our perspectives and questions to the mix.

In this spirit, we are less interested in distinguishing tinkering from other modalities or educational interventions, and more interested in creating a conversation about the kinds of learning opportunities that become possible in particular environments. Some scholars stress the differences between tinkering (as a way of knowing and working) and the kind of planning traditionally involved in engineering or design (Resnick & Rosenbaum, 2013). These distinctions can be useful, particularly considering the differential value placed on linear approaches to engineering and the historical predominance of these approaches in schools. At the same time, we worry about the further dichotomization of what may be mutually generative practices, and the ways like-minded programs or activities may be defined in opposition rather than in conversation.

We view the After-School Tinkering setting as an environment that makes room for different modalities – some moments may look or feel more like tinkering and others may look or feel more like making, planning, art or traditional forms of engineering. The setting is intentionally interdisciplinary. Tinkering is primary insofar as the environment emphasizes the iterative process of learning, and works to cultivate playful experimentation with a range of possibilities and ideas. To this end, we are interested in the ways improvisation and experimentation can enrich the process of making, and the ways planning may be a productive tool within tinkering activities. These various modalities are ultimately in the service of creating rich experiences and opportunities for young people.

We therefore understand tinkering as a disposition towards design and making characterized by iteration and playful experimentation (Resnick & Rosenbaum, 2013). This emphasis on iteration helps to reframe "mistakes" or "failed attempts" as *drafts* – moments in the process of creation that offer insight and fertile ground for new ideas. Drafts may therefore be seen as the vehicles through which different ideas are given expression. As Eleanor Ducksworth (2012) states, 'all ideas are welcome when we're trying to figure things out. Not each idea is as good as another idea, but each has to be given its day.' "Lines of becoming" may take shape differently in contexts that value drafts and encourage the expression and pursuit of ideas.

Thus, while tinkering activities have particular parameters and goals (making a musical instrument or a working pinball machine), they are intentionally designed to support multiple pathways and to imply a range of solutions. The parameters of an activity open up a field of possibilities within a particular domain. For example, in making pinball machines, participants in the After-School Tinkering Program first visited a local pinball museum, playing, noticing and diagramming a diverse range of designs. They were then supported to build their own machines, starting with a flat piece of wood that served as a blank canvas – an invitation to imagine and develop their own playing field. The combination of presenting a diversity of models, communicating a sense of permission with individual designs and encouraging the cross-pollination of ideas among participants is characteristic of tinkering activities as they have been developed in our setting (Petrich, Wilkinson & Bevan, 2012).

Rather than a linear or step-by-step process, the process of making is therefore organized in ways that support the pursuit of new possibilities and the invention of alternative forms. These practices also open the field of activity to novel goals and unanticipated problems. For Petrich, Wilkinson and Bevan (2013) the emphasis on participants' own questions and objectives is part of what distinguishes tinkering from engineering challenges that set predetermined goals ("a building reaching a certain height or a ball rolling down a ramp at a certain speed"). They argue that "the process of becoming stuck and then 'unstuck' is at the heart of tinkering" and that "having an artifact to point to – an artifact that may be rickety or lopsided, but yet has resolved the problem that so puzzled the learner" is part of what makes tinkering activities compelling to learners (2013, p. 55-56). Pedagogically, this involves offering suggestions, making efforts to learn about students' ideas and goals, and supporting the development and complexification of projects on their own terms.

Embedded in this approach is an understanding of goal-development and problem-finding as cognitively rich activities, and as potential sources of ownership. Skills and tools take on new meaning when they are needed to solve a pressing problem or reach a desired goal. Educators may therefore invite young people to dwell a bit longer in the moment between encountering a problem and settling on a solution – to imagine and test different possibilities, and to 'trust the hand as a way of knowing' (Tinkering Studio, 2012; Sennet, 2009). As Espinoza writes, "making seems to be cognitively and socially richer than assembling as it involves more active testing and fitting and less routine following of directions" (2011).

Though the intellectual affordances of this approach are commonly referenced in the discourse on making and education, the Afterschool Tinkering Program has also been working to design tinkering as a "socially rich" activity. This aspect of the pedagogy has been strengthened over time based on our observations of the ways children deepen their engagement when tinkering is connected to a social purpose. In the case of pinball machines, for example, each child's invention became part of a culminating pinball arcade, with parents, siblings, Boys and Girls Club staff and peers serving as patrons. Participants hosted their machines, stepping into the shoes of a pinball machine inventor, and contributing their designs to a larger collective project – one that had the power to transform the local library into a lively pinball arcade. Similarly, a unit that focused on inventing musical instruments culminated in a collective performance. Following the example of one of the facilitators (himself an artist and instrument builder) a number of participants took on the role of conductor and led their peers in a composition. In both cases, individual artifacts took on new meaning as part of a larger social creation. Thus, finding meaningful opportunities for participants to share their work – both in the process of making and as a culminating social activity – can deepen engagement, encourage connections across artifacts and their makers, and create openings for children to stretch into new roles and practices. Goal development and design are also given direction by the broader social purpose of the activity.

Finally, our approach to tinkering treats play as a vital context for thinking and learning. In its capacity to envelop us in a story ('we are mad scientists who invent scribbling machines!' [FN1, 05/2012]) play can be a rich developmental space - one that allows us to treat boundaries as malleable (Resnick & Rosenbaum, 2013), imagine and experience alternate realities, experiment with new roles and "act a head taller than ourselves" (Vygotsky, 1978). Thus, taking apart a clock or drill to see what's inside [Video_4, 10_18_12] or inventing a "nature bot" made of wood, leaves and an offset motor that takes on the name "bossy" once students see how it moves [Video_19, 03_26_13] taps into aspects of play that young people tend to be well versed in: drama, narrative, humor and the imaginative repurposing of everyday materials. This does not mean tinkering is void of frustration or difficulty. Indeed, learning how to work through frustration is a common part of the tinkering process in the after-school settings. Rather, to ground learning in play is to draw on children's strengths, and to create a potentially deeper sense of challenge, purpose and possibility.

As Edith Ackermann (2010) writes:

> Both design and play involve breaking loose from habitual ways of thinking, and making dreams come true!

This, in turn, requires 1. An ability to imagine how things could be beyond merely describing or representing how things are (ask what if, do as if, inventing alternative ways); and 2. A desire to give form or expression to things imagined, by projecting them outward (thus making otherwise hidden ideas tangible and shareable). Both are about building and iterating.

Tinkering is therefore a playful and subjunctive modality – one often replete with the utterance and practice of *what if, could be, maybe, perhaps, let's try it out,* etc. These phrases and ways of approaching materials may be seen as the sensibilities modeled and encouraged by educators in a tinkering setting, grounded in an effort to recognize and deepen the educational potential of the fantastical.

Ackermann also points to the sense of transparency that comes with making "hidden ideas tangible and shareable." As we turn to a discussion of teaching, learning and equity, we see a resonance between the principle of transparency that underlies many tinkering activities (the use of familiar and everyday materials, the invitation to see how and why things work the way they do, the treatment of ideas as public rather than private property) and the ways good teachers make practices, concepts and skills transparent – available for contemplation and appropriation. Indeed, learning environments that feel *inclusive* tend to be adept at distributing and making visible the know-how essential to the practice at hand (Espinoza, 2011). Thus, naming tricks of the trade or sharing the 'why' of a practice ('hold the hammer towards the back of the handle a bit more so you can get some force') can be one way to invite novices in. It is also where the presumed binary between the intelligence of the mind and the hand begins to fall away.

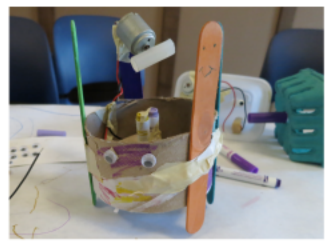
EQUITY-ORIENTED PRACTICE

We argue that equity-oriented goals influence the pedagogical practice of tinkering in particular ways. Our emergent design principles reflect this finding and guide our discussion of key examples, below. We have found that equity-oriented practice in the After-School Tinkering settings is grounded in:

- Building generous learning environments that emphasize shared activity, process and iteration
- Cultivating play, imagination and creativity
- Widening definitions of learning, intelligence and science
- Treating learning as a purposeful and social endeavor. This includes making STEM concepts and practices explicit in ways that are organic and meaningful to the activity.

We argue that approaching tinkering/making from an equity-oriented perspective involves attending to these principles with an understanding of the ways historical inequities (along the lines of race, class, gender, etc.) can be reproduced or challenged in practice. Some or all of these elements can be found in many making environments. However, we believe they take on new meaning in the context of working with young people whose resources and capacities are often overlooked by narrow notions of intelligence and dominant representations of science, and whose schooling is characterized by the kinds of test-centric and regimented curriculum that disproportionately effect working class students and students of color. Providing equitable opportunities to learn is therefore a continuous process of pedagogical design and practice that involves 1) understanding where students are coming from (their social and educational histories and trajectories of participation in the setting) and 2) leveraging the elements that define tinkering to create intellectually respectful and socially meaningful educational experiences. In this section, we share examples that help illuminate what this looks like in practice, and draw connections between iteration, play, and widening definitions of learning, intelligence and science.

An example of a tinkering activity is the Scribbling Machine, a motorized device, made with small battery-powered motors, markers and other common materials, that moves in unusual ways and leaves a mark to trace its path. In making a Scribbling Machine, participants engage with concepts of basic circuitry, vibration, kinetic motion, and symmetry while working towards realizing an aesthetic vision of what kind of drawing they want their machine to make. Participants experiment with changing the length of the weight that off-sets the motors, test various drawing tools, and try a variety of materials to build a body which produces varying motions and patterns. Through the magic of googley eyes, Scribbling Machines often become characters with their own identities, stories and relationships to other kids' machines.



We introduced this activity on the first day of the after-school program. The lead researcher on our team (Shirin Vossoughi) was working with a young girl (Joanna[1]) as she designed her machine, taping down different parts and testing it out to see the kinds of movements and designs it would make on a table, which had been covered with white butcher paper. Towards the end of the day, she said:

"I've had so many drafts."

And a few minutes later:

"I had so many ideas today!" (FN1, 04_27_12)

These comments offer a window into a key moment in the process of tinkering, particularly for children who are new to the program: the few seconds after a participant tests their invention for the first time. Consider some of the default ways we might interpret the initial movements of our machine, particularly when it may not quite work the way we expected or wanted it to: 'Mine doesn't work,' 'I can't get it,' 'I'm not good at this,' etc. Indeed, these are some of the comments we have heard kids make in their initial attempts at an activity. They reflect the premium that can exist on 'getting things right' in high-stakes settings, one of the many ways students are measured and asked to perform knowledge. There is something quite powerful, then, about re-framing this moment as an opening, or a beginning. Like stepping into the shoes of a mad scientist or inventor, the language of "tinkering" offers us stories about what it is we are doing, stories that can influence how we interpret the moment when our invention looks

[1] All student names are pseudonyms.

us in the face and says: 'yes, keep going' rather than 'No, I don't work.'

Joanna's comments also felt significant because she shared them with so much pride. Perhaps this is one example of the new kinds of experiences (of the activity, of the self) that open up when smartness gets widened or re-defined, and when learning is organized to create an ethos of second chances. Since this day, "drafts" and "ideas" have been a staple component of the language used by educators in the program, an example of the many ways students contribute to the evolution of the learning environment.

This brings us back to the role of teaching. The lead educator on our team (Meg Escudé) has adopted and developed a pedagogical vocabulary that emphasizes the process of iteration and the development of ideas. On any given day, one can hear her (and, increasingly, other facilitators) looking over a students' project and saying, "I really like your design," or encouraging participants to "test it and see what happens." In addition to the ways this language is used in one-on-one or small group interactions, Meg often emphasizes process and iteration in the whole group "circle time" that begins each day of the after-school program. During this time, all participants (children, teens and adult facilitators) sit together in a circle to learn about the day's activity, build community and talk about ideas, questions and plans.

The following example is drawn from the first day of the second semester of the program. The activity for the day was making fused plastic science notebooks – individual journals that would become an archive for kids' ideas and plans throughout the semester. During circle time, Meg asked each person to share a favorite photograph and talk about what it means to them. Many of the students chose to share a picture of their family. After going around the circle and giving everyone a chance to describe their picture, Meg connected the discussion to the role of the science notebooks:

> "So pictures, they're like history, right? History books are full of pictures. But you have your own histories at home too, that's the history of your own life…so your notebooks are going to be kind of like that - what we're making today are science notebooks - and they're going to be a place for you to go back, all throughout the semester and **draw or write about discoveries you had, or things you were excited about that you were building, or ideas you want to try that you didn't get to try, or all kinds of stuff, whatever you like. But we, in this class, in this program, we're really interested in the things you get most excited about while we're making things.** Because sometimes we make things, in this program, that we don't get to take home…can you guys think of anything we made over the summer that we took apart?"
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> A few hands shot up. Esperanza said, "the rocket ship!" Tanya added, "the robots" referring to scribbling machines and Meg responded, "so sometimes the scribbling machines don't last that long, or the rockets don't last that long, **but what happens to the ideas you had while you were making that? Do they go away too when you take it apart?"** Shauna responded, "Nooo."
>
> Meg echoed: "Noo, that's right. So you hold on to those ideas and **just like a family picture if you write down some of those ideas or you draw about what you made, it will help you later when you are working on more problems and more projects**. So that's how we hope that these notebooks will be useful to you throughout the semester" (FN3; Video 2; 09_24_12).

Here, Meg invited participants to treat their ideas the same way they would a cherished family photograph, elevating the kinds of thinking and making students would be doing in "this class" as worthy of honoring and archiving. Ideas are privileged as the most valuable part of the process. The artifacts themselves are important but may not "last too long;" the thinking is what matters and potentially endures. Meg's language is also proleptic and future oriented; young people are invited to see themselves as thinkers, poised to develop ideas and make significant discoveries. There is an important sense of pedagogical transparency and authenticity communicated here. Meg introduced the notebooks not as something you "have to" do, but as a tool for time travel, idea-creation, and memory. The teacher's hopes are made visible, alongside what can be seen as a promise to approach the science notebooks (and activities) in ways that feel useful and meaningful.

If and how did students take up the values and practices being emphasized here? Our efforts to study learning in this setting include attending to the sometimes unanticipated ways participants embody the disposition towards tinkering (process, iteration, ideas, play) modeled and emphasized by educators. On the last day of this same semester, the after-school program culminated in the community pinball arcade (described above). During the circle time for that day, Meg asked students to reflect on the many projects they had worked on in the previous months. She also handed out pictures of each participant's pinball machine in process – capturing the various drafts each had undergone. She invited everyone to write in their notebooks about the pictures and their experience of the making process.

Aeden, one of the young boys in the program, decided instead to display his pictures on the pinball machine itself:

Here we see each draft of his artifact (starting from left to right) displayed, culminating in the final version of the machine itself. Aeden's mother, father, younger brother and sister (herself a participant in the program) had a chance to learn about and play his pinball machine, with Aeden serving as the creator and guide. Similar to our discussion of Scribbling Machines (above), Aeden's decision to display his photographs publically suggests that he felt a sense of pride in the process itself, not only in the final product. It also illustrates how one student interpreted the emphasis Meg placed on documenting the history of one's thinking, and on ideas as the most valuable part of making. In addition to her earlier introduction of the science notebooks, Meg's decision to give each child photographs of their artifact reinforced the value she saw in their process, and invited them to see it as well. Thus, cultivating generous learning environments characterized by an emphasis on process/iteration, the availability of support and an ethos of 2nd, 3rd, 4th chances is an ongoing pedagogical practice, embodied in multiple ways and reinforced over time.

In a later interview, Aeden shared that he decided to place the pictures on his machine in order to 'show how I started, how I was later on and how I was at the end.' He also expressed that it was important to "look back" at one's work, and let us know that he still has the pinball machine at home (Interview, 06_12_13). These reflections – about six months after the original creation of the artifact – suggest a relationship between emphasizing process and iteration and supporting young people to reflect on and feel a sense of ownership towards their own learning. The fact that Aeden felt it would be ok to do something different with his pictures (putting them up on his pinball machine rather than in his notebook) also reflects a sense of permission to engage in activities in an unconventional way.

As researchers and educators, we have been speculating that such an environment contributes to widening definitions of learning, intelligence and science and creates openings for young people who may not be positioned as "successful" according to the more narrow measures that (increasingly) characterize learning in school. Studying and grounding this speculation in the experiences of students themselves has involved close observations of educational activity as well as interviews with children and parents. Aeden's mother, for example, shared her perspective on his experience in the After-School Tinkering Program, describing what she believes it has meant for him. Notice, in particular, how some of the themes from Meg's discussion of the science notebooks (meaningful and interesting activities, valuing process, connections to home) re-emerge:

> "You know, they do so much homework…he, because he struggles more than Shauna [his sister]… I think having an outlet to do something, though he doesn't get that its on an educational level, he thinks its playing and its fun and…**it doesn't seem like its an assignment or homework or something I *have* to do, its more fun…**
>
> With him, from early on, it's bringing it out in him. Because I tell people, you know, he's very intelligent. Of course I'm biased, I'm his mom. But, you know**, its just the way you go about interacting with him** that you kind of have to draw it out of him. He's not the child – like his sister – that's going ooh ooh ooh I know the answer… With him, its being able to be successful in making whatever he makes and saying '**mom mom look what I did, I came home and I did this…'**
>
> He loved, absolutely loved making the musical instruments…**it was something that he really took pride in and couldn't wait to come home and show me**. And then, to take it a step further, with going into my Tupperware box, finding a rectangular Tupperware shape, putting bands on it and then showing me how, **'listen mom, this is making music, see I made my own thing like in tinkering.**' I thought that was pretty funny, **yet amazing. Because I though ok now you are applying things that you're learning here to just everyday situations** which you know, before, you didn't do as much…you really weren't taking it to that next level like I hoped you would." [Interview, 07_03_13]

Here, we see ideas and practices from the after-school setting traveling home in ways that signal deepening forms of learning and engagement. Using familiar materials and connecting STEM concepts with everyday life may therefore support young people to make connections across settings, and to carry forward the practices of inventing and creating. Aeden's mother also identifies the setting as offering a different kind of learning experience and 'drawing out' his potential. Her comments suggest a relationship between grounding learning in the absorbing, interest-driven aspects of play and providing opportunities for young people to experience themselves as successful in an educational setting.

We have also noticed multiple instances when ideas and practices travel from home or school into the after-school setting, creating new possibilities for learning. Educators are intentional about drawing these connections and inviting students to bring their full selves to the program. In one such instance, the lead researcher (Shirin) was working with a young girl (Kitzia), to take apart an answering machine as a way to explore how it worked and to find interesting materials for an upcoming animation activity. Kitzia is a long time participant in the program and also happens to be one of the chief skeptics with regards to whether or not tinkering "counts" as science. During this activity, she shared with Shirin that the activity "doesn't feel like science." This opened up a discussion of what science means. Shirin asked Kitzia if she had ever dissected an animal, going inside to see "its guts" (similar to the answering machine). Kitzia responded that her "mom and dad do that" and went on to describe how her parents dissect animals and 'take out their organs' for cooking purposes [Video 4, 10_22_12]. In a later interview, Shirin and Kitiza watched a clip of this interaction together, and Shirin asked if Kitzia's perspective on tinkering and science had changed since their previous conversation. She responded:

> Kitzia: Hmmm. I don't think it feels like science…**it feels like fun, you know.**
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> Shirin: Do you feel like science usually doesn't feel like fun?
>
> Kitzia: A little, **but that was a lot!**
>
> [Interview, 05_20_13]

Similar to Aeden's mother's discussion of the ways he may experience activities as fun vs. educational, Kitzia seemed to draw a sharp distinction between fun and science (the more fun it is, the less scientific, the more scientific the less fun). We have come to appreciate the ways young people are grappling with these definitions as well as the lively conversations about the meaning of science that have emerged in the afterschool program. We see a value in making these discussions explicit and thinking together about what it means to widen received definitions. This involves respecting children's sense of the ways science tends to be defined and engaging with the tensions therein, rather than treating them as misconceptions in need of fixing. These examples have also led us to consider how children's relationships with their own learning and capacities may shift with greater recognition of play as a deeply intellectual activity. We intend to continue pursuing these questions.

IMPLICATIONS FOR TEACHING & LEARNING

> Skill is not an attribute of the individual body in isolation but of the whole system of relations constituted by the presence of the artisan in his or her environment (Ingold, 2000).

Constructionism is often identified as the theory of learning that resonates most strongly with the maker movement. The emphasis within this tradition on learners constructing knowledge through their engagement with materials in the context of a personally meaningful activity (Papert, 1986), and more broadly the constructivist emphasis on discovery and inquiry (Piaget, 1970), reflect many of the principles that underlie the development of tinkering in our context.

While drawing from these traditions, our conceptual and methodological lenses are also grounded in cultural-historical approaches to learning and human development. This tradition defines learning as shifting and deepening participation over time – a social process that contributes to the development of the practice (and the environment) itself (Cole, 1996; Rogoff, 2003). For our purposes, this includes studying the organization of opportunities for young people to experience themselves as knowledgeable participants and contributors within tinkering activities. Methodologically, this involves inquiring into the kinds of development valued and therefore emphasized in a particular setting (Matusov, 1998) as a precursor to looking at how learning unfolds. As with the explicit emphasis Meg placed on process/iteration and the ways it may have influenced Aeden's later participation, we treat the practices and dispositions jointly developed in the After-School Tinkering Program as central objects of analysis, and consider if and how students take up these practices further downstream. This is one of the ways we work to develop a *situated* understanding of learning and equity, rather than starting with generic or predefined measures. In our experience, this approach can help make visible shifts in participation, roles and relationships that may otherwise go under the radar.

Cultural-historical perspectives also complement constructivist views by focusing on the social accomplishment of learning, and the role of pedagogy or teaching. Educators in making spaces or informal STEM learning environments are frequently described as "facilitators." This shift away from the word "teaching" is often meant to distinguish the support offered by adults from more didactic or teacher-centered approaches. While this is important, we worry about swinging to the other extreme in ways that make "teaching" or "pedagogy" taboo words within the realm of tinkering/making and informal STEM education. Minimizing the role of the teacher can shortchange the many generative aspects of pedagogical talk and interaction and forego opportunities to share valuable knowledge with other educators.

For us, redefining learning also means redefining (rather than rejecting) teaching (Escudé, 2012). Echoing Ingold's definition of "skill" as an attribute of a whole system of relations, we view collaboration between experts and novices as an opportunity for the developmentally fruitful distribution of valued practices and skills. Engaging with new tools and materials alongside experienced others who are actively working to support learning and who have a historically grounded understanding of inequity creates a particular context for the kinds of shifts we are interested in cultivating and documenting.

We are interested in the kinds of intellectual respect and opportunity that emerge through such interactions. From a Vygotksian perspective, all learners hold deep knowledge and potential (1978). In practice, this involves adults treating children's talk and engagement as valid and full of potential (Espinoza, 2011), and working to hear the sophisticated thinking in children's budding ideas and questions (Hooper, 2013). As in the conversation with Kitzia, educators can support learners to engage with new roles, ideas, and practices while recognizing and leveraging the cultural, linguistic, and intellectual resources they bring to the setting (Gutiérrez & Rogoff, 2003; Moll et al., 2005). The pedagogical leveraging of everyday experience is all the more pressing for youth whose home and community lives are treated as deficits to be overcome rather than rich resources to draw upon (Gonzalez, et al., 2013).

Parallel to our discussion of teaching, there is also sometimes a tendency within museums and other informal settings to privilege children's implicit experiences of STEM phenomena and practices. Naming scientific phenomena, introducing conceptual language, or asking students to become meta-reflective about their own learning may be framed as too "school like." Though this sensibility often grows from a legitimate concern with excluding or intimidating participants, or reifying scientific terminology at the expense of deep understanding or experience, we find that it can also close off the space for pedagogical experimentation. In the context of equity oriented work, we have found it important to experiment with making STEM concepts and practices explicit without compromising the playful, inquiry-led spirit of tinkering activities. This includes finding organic opportunities to connect children's ideas to the big ideas of science, engineering or physics. Engaging with ideas without making links to the ways those ideas are used in formal educational settings can also reproduce inequities in access and opportunity. Similarly, Nasir et al. (2006) suggest that recognition of the overlap between everyday activities and the "official" activities of science can highlight valuable access points to science for learners who might not otherwise engage in scientific activities. If approached in careful ways, we argue that making STEM concepts and practices explicit can be a form of intellectual inclusion rather than exclusion.

Ray McDermott writes that conventional approaches to labeling particular activities as math or science tend to focus on the more narrow and formal operations of school, leading to the "loss of many students whose everyday mathematical reasoning goes unrecognized, unappreciated and unused" (2013, p. 85). Rather than asking 'what are math and science?' he proposes that we shift to asking: 'When are math and science?' as a way of thinking about *moments* when scientific practices or concepts become useful resources towards some meaningful purpose. As an analytic lens, we find that the latter 'when' question draws attention to human activity and the process of tinkering, whereas 'what' suggests a final or official definition. We also find the question of *when* particularly useful for an After-School setting that treats tinkering as an interdisciplinary activity. Rather than looking for STEM learning in every moment or interaction, we seek to identify the moments when STEM concepts or practices are – or could be - salient with regards to the pursuit of questions and goals integral to the tinkering activity at hand.

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