Afterschool Educators’ Teaching Practices Through Tinkering: Nurturing Student Collaboration, Engagement, and Development of Self-Confidence

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Afterschool Educators’ Teaching Practices Through Tinkering: Nurturing Student Collaboration, Engagement, and Development of Self-Confidence

A Thesis Project Presented to
The Faculty of the School of Education
International and Multicultural Education Department

In Partial Fulfillment
Of the Requirements for the Degree
Master of Arts in International and Multicultural Education

by
Lianna Kali
December 2018
Afterschool Educators’ Teaching Practices Through Tinkering: Nurturing Student Collaboration, Engagement, and Development of Self-Confidence

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MASTER OF ARTS

in

INTERNATIONAL AND MULTICULTURAL EDUCATION

by

Lianna Kali
December 2018

UNIVERSITY OF SAN FRANCISCO

Under the guidance and approval of the committee, and approval by all the members, this thesis has been accepted in partial fulfillment of the requirements for the degree.

Approved:

Rosa M. Jiménez, Ph.D.
Instructor/Chair

December 2018
Date
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ACKNOWLEDGEMENTS

*Lutu na niu, lutu ki vuna*

Where the coconut falls, it grows

-Fijian proverb

*Vinaka vaka levu* and *lolomas* to my family, friends, professors, and colleagues who supported me through this journey!
ABSTRACT

Since the early 2000s constructionist pedagogy has become an increasingly popular trend in both formal and informal science, technology, engineering, art, and math (STEAM) learning environments to support transformative educational outcomes through the making of personally meaningful objects and artifacts. But with this rise in popularity comes a challenge for educators: understanding what are the teaching practices that are most effective in a maker-centered learning environment to support student learning. Through an ethnographic case study of the teaching practices in a tinkering afterschool program, this study examines the core pedagogical facilitation moves of tinkering educators and investigates how those moves support student learning. Analysis and reflection on the dataset shows that tinkering educators’ pedagogical practices strongly support student engagement with real tools and materials, collaboration with fellow youth and adult facilitators, and development of self-confidence. The specific teaching practices can be organized into a pedagogical framework I have developed, and fall into three main categories: 1) invitations to participate, 2) investigations into phenomena, and 3) introspection on process. The study concludes that open-ended questions throughout the building process and the development of a rich and supportive intellectual environment are major factors in youth learning through tinkering.

Keywords: making and tinkering, afterschool education, informal education, constructionism, STEM learning, critical pedagogy
CHAPTER 1
INTRODUCTION

Statement of the Problem

Since the early 2000s constructionist pedagogy has become an increasingly popular trend in both formal and informal science, technology, engineering, art, and math (STEAM) learning environments to support transformative educational outcomes through the making of personally meaningful objects and artifacts. Spaces for maker-centered learning can be found in K-12 classrooms, museums, libraries, afterschool programs, and other informal spaces (Douherty & Conrad, 2016). This approach to education is based on the idea that understanding is constructed in the mind of the learner, and that it is best mediated through building personally meaningful physical or digital artifacts (Papert, 1980).

But with this rise in popularity comes a challenge for educators: understanding what are the teaching practices that are most effective in a maker-centered learning environment to support student engagement, collaboration, and development of self-confidence, and finding ways to implement them. This can be particularly difficult when it looks like the students are having fun or playing, but an outside observer may not be able to identify the learning that is taking place (Petrich, Wilkinson, & Bevan, 2013). Additionally, maker-centered learning environments are intentionally learner-driven. Martinez & Stager (2013) point out the risk that many may conceptualize this as meaning there is no instruction or that adults in these spaces should be totally hands-off, when in fact there is a high level of nuance and a practiced skill set required to create environments that foster rich investigation of all learners’ ideas. This study attempts to address this problem by examining and identifying the pedagogical strategies and techniques used by a group of educators working in an informal, constructionist learning
environment and correlating those practices to outcomes that demonstrate student agency, engagement, and inquiry through tinkering.

**Background and Need for the Study**

*The Culture of “Making”*

Though the act of “making” has existed as a human practice since ancient times, the Maker Movement, as it has come to be called, is a relatively recent phenomenon. It emerged in the early 2000s growing out of the tradition of hackerspaces, computer clubs, and FabLabs, and the term “maker” was officially coined in 2005 with the publication of the first issue of *MAKE:* magazine (Dougherty & Conrad, 2016). As an approach to learning, making focuses on several core principles such as learning by doing, iteration and failure as part of the process, developing fluency with tools and materials, facing challenges as being part of the fun, creating objects that are personally meaningful, and working both autonomously and collaboratively (Papert, 1980; Wilkinson & Petrich, 2013).

While the philosophy of making and the Maker Movement is framed through language of inclusivity, in practice a tension exists between those who *are* makers of objects and those who identify as *makers* (Clapp, Ross, Ryan, & Tishman, 2017). Maker-centered learning environments face the challenge of providing representative examples of what “counts” as making that are inclusive of the rich and varied culturally-grounded practices of non-dominant groups. The making practices of women and people of color are often excluded from the social and educational framing for what is represented as legitimate making. High-tech tools and materials that are stereotypically gendered as masculine, like robotics kits and 3D printers, are framed as superior forms of making, whereas low-tech tools and practices that are gendered as feminine, such as sewing and repair work, are seen as less innovative and inconsequential
(Chachra, 2015). In classroom and afterschool learning environments, this narrow and exclusive framing is further complicated by the national trend that educators shaping and implementing curriculum tend to come from privileged, white backgrounds and serve an increasingly non-white, multiply-marginalized student population (Kumashiro, 2012).

In her closing keynote address at Stanford University’s FabLearn Conference, Leah Buechley (2014) presented an analysis she did of the covers of *MAKE:* magazines. She found that over nine years and 39 covers, the magazine showed 41 people. Of those 41, 85% were men and boys, 15% were women and girls, and 0% were people of color. This shocking disparity in representation in terms of both gender and race highlights the ways the Maker Movement, as it exists now, can alienate both women and people of color in how it presents who qualifies as a maker. Buechley went on to analyze the content of what was presented on the covers and found it weighed heavily towards electronics, vehicles, robots, rockets, and music, and elaborated on what’s not represented, specifically the rich making practices of women and people of color around the world. When tying these findings to the *MAKE:* editorial staff, it was no surprise that she discovered that of the 15 people on staff, 87% were men, 13% were women, and 0% were people of color. While *MAKE:* magazine is not the final, authoritative voice for the Maker Movement as a whole, their position of power as a leader in the field does shape social perceptions of what ideas and practices are valued within this community of learners.

Implications for the Field

With this cultural context in mind, educators in constructionist, maker-centered learning environments must be actively aware of how to both support and value the ideas *all* students bring to their tinkering practice. There is an extensive body of literature that strives to identify student learning, engagement, practices, and agency through making and tinkering (Gutwill,
Hido, & Sindorf, 2015; Brahms & Wardrip, 2014; Clapp, Ross, Ryan, & Tishman, 2017; Bevan, et al., 2018) in both informal and K-12 environments, but scholars note there is far less research on the pedagogical practices that support these outcomes (Vossoughi & Bevan, 2014; Ryoo, Kali, & Bevan, 2016). What is documented tends to surface high-level, broad generalizations of a few types of educator moves without delving into the deeper reasoning behind these approaches.

**Purpose of the Study**

This study examines the core pedagogical facilitation moves in two maker-centered afterschool learning spaces, and investigates how those moves support student engagement, collaboration, and development of self-confidence. I draw on constructionist theories and critical pedagogies as my theoretical framework. The aim of this qualitative study is to clearly articulate these pedagogical practices in a way that can be useful to both practitioners in the field of constructionist education as a guiding tool, as well as to the partner organization research site as documentation for key stakeholders. It builds on existing theories around research-practice partnerships (Coburn & Penuel, 2016) to develop materials that are beneficial for all parties involved in tangible ways.

The study took place in collaboration with the Tinkering School and focuses on the teaching practices of tinkering educators in afterschool programming held for two Boys and Girls Club locations. The youth in the program are third and fourth grade students in two historically working-class neighborhoods of San Francisco. The data was collected through a combination of interviews and site observations, and was reviewed collaboratively with the educators.
Research Questions

This study is grounded in the following research questions:

1. What are the teaching practices used by tinkering educators in an afterschool learning environment?
2. In what ways do the educators identify participation in the tinkering program as being important for the youth?
3. What are the educators’ primary pedagogical goals?

Theoretical Framework

My research draws upon constructionist pedagogy and critical pedagogies that support student collaboration, engagement with learning, and development of self-confidence. Constructionism and critical pedagogy frameworks are highly complementary yet are rarely linked. By making explicit connections between how hands-on learning can lead to transformative outcomes, I hope to advance understandings in the field of how tinkering can become a more educationally equitable teaching practice.

Constructionist Learning

Many maker-centered learning environments practice a constructionist philosophy on learning and pedagogy. Though Seymour Papert has been referred to as the “father of the Maker Movement” (Martinez & Stager, 2013, p. 17), the foundations of theories around maker-centered learning rely not only on his work, but on the work of other progressive educators too, such as John Dewey, Maria Montessori, and Jean Piaget (ibid) and the sociocultural theories of learning of Lev Vygotsky (1980). Dale Dougherty (2016), a current leader of the Maker Movement and advocate for maker-centered learning, cites Dewey’s idea of “experimental play” as a key inspiration for developing a maker mindset (p. 149). Learners are actively formulating ideas and
testing them, and the playful approach makes it a low-stakes, safe environment in which to learn. Dewey’s ideas of learning through experience and observation (Martinez & Stager, 2013) are deeply tied to maker-centered learning practice. Montessori, a contemporary of Dewey, advocated for a hands-on approach to learning with a particular emphasis on materiality. Her methods also relied on creating an environment where students could be self-directed, independent learners (Dougherty & Conrad, 2016). This theme of learner-driven experiences will be significant in the following analysis of my research question.

Building on the traditions of Dewey and Montessori, Piaget formalized these theories into the idea of constructivism – that learners are not passive recipients of knowledge, but rather construct their understanding of a phenomenon or idea based on experience (Martinez & Stager, 2013). Papert, a student and colleague of Piaget, elaborated on this idea and coined the term constructionism, in which he argues that learning is best served when creating a personally meaningful object (Papert, 1980). Trained as a mathematician, Papert became fascinated with the potential for learning he saw when students could program computers and robotic devices called Turtles as “objects-to-think-with” (ibid, p. 11) rather than as tools to transmit knowledge. He describes this learning as:

When a child learns to program, the process of learning is transformed. It becomes more active and self-directed. In particular, the knowledge is acquired for a recognizable personal purpose. The child does something with it. The new knowledge is a source of power and is experienced as such from the moment it begins to form in the child’s mind. (1980, p. 21)

This learning process was interdisciplinary, as students engaged with literacy (by learning to “speak” the computer’s programming language LOGO), math, and aesthetics (the Turtle could
draw, make sounds, and move as if “dancing”), and also supported practicing computational thinking concepts such as debugging, abstraction, and looping.

Vygotysky’s (1980) sociocultural theories of learning are also an influence on maker-centered learning environments (Gutwill, Hido, & Sindorf, 2015). Making, as a practice, is not just focused on knowing and doing, but also on notions of being and becoming as a function of learning (Petrich, Wilkinson, & Bevan, 2013). Vygotsky’s idea of the Zone of Proximal Development (ZPD) is enacted in maker-centered learning (Martinez & Stager, 2013). As learners in these environments strive to understand the affordances and limitations of working with physical objects, they are playfully and meaningfully engaging with the edge of their understanding and pushing past those boundaries towards new learning. In a Vygotskian sense, they are in the ZPD because they are “acting beyond” what they are currently capable of understanding. This learning is also socially situated; the process of learning from and sharing with others is constantly underway.

Critical Pedagogy for Transformative Learning

A non-hierarchical approach to learning is a core component of tinkering pedagogy and can be tied to critical pedagogy through Freire’s critique of the “banking model” of education. In Pedagogy of the Oppressed he describes how teachers “must be partners of the student in their relations with them” (1968, p. 75). Teachers are not dispensing knowledge into students, but rather are there to help students understand their relationships with the world (or in the case of making: with tools, materials, and processes) through “problem-posing” (p. 79). Freire also believes that there is no teaching without learning which also relates to maker-centered education in that educators aim to learn from those they are facilitating. In these spaces, expertise is
distributed and can be sought from a variety of sources including the educators present, fellow activity participants, and even the tools and materials in the learning environment.

Practicing inquiry is a fundamental principle of maker-centered learning. Freire describes how this process has potential for transformative outcomes. He states, “knowledge emerges only through invention and re-invention, through the restless, impatient, continuing, hopeful inquiry human beings pursue in the world, with the world, and with each other” (1968, p. 72). The concepts of invention and re-invention are indicators of engagement through tinkering and are often referred to as iteration. As learners pursue their own questions and ideas, they act “in the world” to devise, test, and refine solutions. Freire elaborates on this idea by stating, “any situation in which some individuals prevent others from engaging in the process of inquiry is one of violence. The means used are not important; to alienate human beings from their own decision-making is to change them into objects,” (p. 85). Educators in maker-centered learning must remain vigilant in their pedagogy to support each learner’s individual inquiry practice to support transformative outcomes.

Furthermore, this hands-on approach to learning relates to hooks’ theory of engaged pedagogy (1994). Learners are not disengaged from their bodies, and instead are acutely aware of their actions and the impact they have on the objects they are designing and the community they’re interacting with. hooks critiques the concept that there should be a split between mind and body in educational spaces, and instead argues that a holistic approach for both educators and students leads to more powerful learning and deeper self-actualization. Another component of engaged pedagogy is that it “necessarily values student expression” (p. 20). Tinkering and maker-centered learning differ from traditional STEM projects in the way they incorporate art
and aesthetics as equally valuable components in the process as a means for learner self-expression.

Where maker-centered learning has potential to connect more deeply with critical pedagogies is by building on the ways educators support learner-driven experiences by incorporating culturally relevant pedagogy. Maker-centered learning is already good at leveraging student interests and skills for academic success, and can be improved by structuring activities in ways that they can maintain cultural competence and support consciousness-raising (Ladson-Billings, 1995; Freire, 1974).

**Methodology**

This exploratory case study takes place in collaboration with the Tinkering School, an informal education organization that offers camps, classes, and afterschool programming based on constructionist practice to elementary- to high school-aged youth in the San Francisco Bay Area. They operate under the philosophy that “kids are more capable than they know, freedom to fail is essential, and it [making] can be done bigger and bolder” (Tinkering School website, 2018). This study is situated around programming conducted by the Tinkering School for two local Boys & Girls Clubs (B&GC) – the Mission Neighborhood Clubhouse and the Willie Mays Clubhouse in the Bayview-Hunters Point neighborhood. The study will focus on the teaching practices of three Tinkering School educators and two B&GC staff collaborators. The clubhouses serve low-income youth of color (primarily Latinx and African American), and the Tinkering School program staff members are white, young adults. Sessions are held on Tuesdays for the Mission Clubhouse and Thursdays for the Willie Mays Clubhouse. Each program has 12-14 participants who are third and fourth graders. I attended nine 90-minute programming sessions
and participated as an observer/facilitator. I also participated in the post-program educator reflection sessions, which lasted for about 30 minutes on average.

As a researcher, I am deeply grounded in the community of tinkering educators as that is my primary role in my job outside of my studies, and I have also participated in developing and leading afterschool tinkering programs for low-income youth of color. I have worked as an informal educator in a museum setting for over ten years developing, testing, and facilitating constructionist learning experiences to museumgoers of all ages. In my role, I also lead professional development workshops for teachers, museum professionals, librarians, and afterschool educators that focus on developing a tinkering disposition to lead tinkering activities in their own environments. This professional and pedagogical background impacts my positionality as I am able to enter tinkering learning spaces as a researcher with an established understanding of the field and its norms.

This study implemented Community Based Participatory Research methods (Burns, Cooke, & Schweidler, 2011) in the process of determining the research question, gathering data, and analyzing findings. In this methodology, it is important to ground the study in the existing knowledge of the community and focus on a specific location. The communities this study focuses on are educators who implement tinkering pedagogy and the local B&GCs these educators serve. My goal of this research is to deepen my understanding of teaching practices to support collaboration, self-confidence, and engagement through constructionist activities by observing another organization’s approach, and document them in a way as to be accessible to others in the field.

In order to triangulate findings, research was conducted using a combination of qualitative methods. The process began with holding baseline half hour-long interviews with
Tinkering School and B&GC educators to ground the research in their personal pedagogical approaches to teaching through tinkering. Next, I conducted site visits and took fieldnote observations as a participant ethnographer of nine 90-minute afterschool tinkering sessions focusing on the teaching practices of the Tinkering School educators. Following these sessions, I also participated in the educators’ debrief “Delta/Plus” conversations to highlight what observations, surprises, and questions came up for the educators during the day’s session after the youth have gone home for the day. Through these multiple data sources I interrogate and categorize what pedagogical practices are most effective in supporting learners’ collaboration, engagement, and development of self-confidence and aggregate these findings into a tool that can be useful for both the Tinkering School as an organization and for other constructionist educators. Data sources and their connections to the research questions are organized according to the following scheme (Table 1.1):
Table 1.1: Data Collection and Research Questions

<table>
<thead>
<tr>
<th>Data Source</th>
<th>Collection Window</th>
<th>Research Question Addressed</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 Educator Interviews</td>
<td>6 weeks</td>
<td>Q2-In what ways do the educators identify participation in the tinkering program as being important for the youth? Q3-What are the educators’ primary pedagogical goals?</td>
</tr>
<tr>
<td>30 minutes per interview</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Audio Recordings &amp; Transcriptions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 weeks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 Site Visits – Tinkering Sessions with Youth</td>
<td>2 months</td>
<td>Q1-What are the teaching practices used by tinkering educators in an afterschool learning environment?</td>
</tr>
<tr>
<td>90-minutes each Observer/Facilitator Sessions in afterschool sites with Fieldnote Documentation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 months</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 Educator Debrief Meetings – Delta/Plus Reflections</td>
<td>2 months</td>
<td>Q1-What are the teaching practices used by tinkering educators in an afterschool learning environment? Q3-What are the educators’ primary pedagogical goals?</td>
</tr>
<tr>
<td>30-minutes each Participant/Observer with Fieldnote Documentation</td>
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</table>

Data Analysis

Based on my interviews and observations of the program sessions, I developed an emergent coding scheme (Table 1.2) to describe common traits that were present across the educators’ practice that had an impact on youth self-confidence, engagement, and collaboration in the program. This coding scheme was used to analyze interview and fieldnote data, and provided a framework for organizing the findings.
### Educator Pedagogy

<table>
<thead>
<tr>
<th>Primary Pedagogical Goals</th>
<th>Defining Tinkering</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Welcoming and Safe environment</td>
<td>1. Hands-on/kinesthetic</td>
</tr>
<tr>
<td>1.1. Addressing physical needs of youth</td>
<td>2. Freedom or creativity with ideas</td>
</tr>
<tr>
<td>1.2. Addressing emotional needs of youth</td>
<td>3. Having the ability to make mistakes</td>
</tr>
<tr>
<td>2. Culture of ‘yes’</td>
<td>4. Playful approach</td>
</tr>
<tr>
<td>3. Asking questions</td>
<td>5. Mindset/process (not about product)</td>
</tr>
<tr>
<td>3.1. To draw out student ideas</td>
<td>6. Problem solving</td>
</tr>
<tr>
<td>3.2. To check for understanding</td>
<td></td>
</tr>
<tr>
<td>3.3. Instead of giving answers</td>
<td></td>
</tr>
<tr>
<td>4. Support learning through doing</td>
<td></td>
</tr>
<tr>
<td>4.1. Hands off the tools</td>
<td></td>
</tr>
<tr>
<td>4.2. Demonstrate trust in youth</td>
<td></td>
</tr>
<tr>
<td>4.3. Encourage failure</td>
<td></td>
</tr>
<tr>
<td>4.4. Encourage iteration</td>
<td></td>
</tr>
<tr>
<td>4.5. Making connections to familiar things</td>
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<tr>
<td>4.6. Offering scaffolding or support as needed</td>
<td></td>
</tr>
<tr>
<td>4.7. Demonstrating tool use (but not doing it for youth)</td>
<td></td>
</tr>
<tr>
<td>4.8. Allowing for making mistakes</td>
<td></td>
</tr>
<tr>
<td>5. Facilitate collaboration and conversation</td>
<td></td>
</tr>
<tr>
<td>6. Break down student-teacher hierarchies</td>
<td></td>
</tr>
<tr>
<td>7. Encouraging reflection and acknowledgment of self and others</td>
<td></td>
</tr>
<tr>
<td>7.1. With youth</td>
<td></td>
</tr>
<tr>
<td>7.2. With each other</td>
<td></td>
</tr>
<tr>
<td>7.3. Praxis: revisiting goals and intentions</td>
<td></td>
</tr>
<tr>
<td>8. Accountability to Group Agreements</td>
<td></td>
</tr>
<tr>
<td>9. Redirection to support/continue engagement</td>
<td></td>
</tr>
<tr>
<td>10. Set daily goal or intention</td>
<td></td>
</tr>
</tbody>
</table>

| Impacts of Tinkering on Youth                                                           |                                                                                  |
|------------------------------------------------------------------------------------------|                                                                                  |
| 1. Confidence                                                                            |                                                                                  |
| 1.1. Self-discovery                                                                      |                                                                                  |
| 1.2. Independence                                                                        |                                                                                  |
| 1.3. Empowerment                                                                         |                                                                                  |
| 1.3.1. Take on role of facilitator with other youth                                      |                                                                                  |
| 1.4. Desire to share with community                                                      |                                                                                  |
| 1.5. Assertion of ideas or intentions                                                    |                                                                                  |
| 1.6. Comfort with making mistakes                                                       |                                                                                  |
| 1.7. Learning to use new tools                                                          |                                                                                  |
| 2. Engagement                                                                           |                                                                                  |
| 2.1. Intrinsic motivation                                                                |                                                                                  |
| 2.2. Iteration                                                                          |                                                                                  |
| 2.3. Intuition                                                                          |                                                                                  |
| 2.4. Perseverance                                                                       |                                                                                  |
| 2.5. Retention in the program                                                           |                                                                                  |
| 2.6. Having fun                                                                         |                                                                                  |
| 2.7. Expressing excitement about learning                                                |                                                                                  |
| 2.8. Voicing excitement, appreciation, or support for others                            |                                                                                  |
| 2.9. Learning through doing                                                             |                                                                                  |
| 2.10. Ownership                                                                         |                                                                                  |
| 3. Collaboration                                                                        |                                                                                  |
| 3.1. Learning from each other                                                            |                                                                                  |
| 3.2. Sharing ideas                                                                      |                                                                                  |
| 3.3. Sharing tools & materials                                                           |                                                                                  |

Table 1.2 Coding Scheme for Analyzing Interview Transcripts and Fieldnotes
This is a low-risk study that is grounded in articulating what already exists in the educators’ current practice and praxis. That being said, the process of reflection on one’s own current practice can be challenging if there is a misalignment between intention and impact. In order to conduct this case study in a way that protects the subjects I’ll be working with, this research will be approached collaboratively and with protocols that protect the identities of my collaborators. The research questions were developed in conjunction with the organization. Educators had the opportunity to read and provide feedback on all fieldnotes, as well as the final summary findings of educator pedagogical moves. Pseudonyms will be used for all written transcripts, interviews, and fieldnotes to protect participants’ privacy. All signed consent forms will be kept in a locked cabinet and data gathered will be stored on a password-protected laptop. The research will beneficial to the organization in that they will have documented stories of teaching and learning that they can share with stakeholders.

**Limitations of the Study**

Most notably, this study is limited by a small sample size of educators and a limited set of program observation days. Choosing to attend nine program sessions is an artifact of the program calendar. Nevertheless, I believe the data collected is a rich set with lots of strong examples of educator pedagogy to draw from. Primary sources such as the in-depth interviews and post-program reflections help strengthen the data set as a way of addressing some of these limitations.

**Significance of the Study**

This study is significant in both the macro and micro scale. For the field, it enriches and expands on the current body of research in the field of constructionist learning. The current body of research extensively covers designing physical spaces for tinkering (Peppler, Halverson, & Kafai, 2016a; Honey & Kanter, 2013) and identifying learning through tinkering (Peppler,
Halverson, and Kafai, 2016b; Gutwill, Hido, & Sindorf, 2015; Brahms & Wardrip, 2014), but there is significantly less work on identifying educator pedagogical moves and correlating those actions to student collaboration, self-confidence, and engagement. The findings articulate the educators’ pedagogical goals and teaching practices to clearly identify impact on youth learning. I have distilled these field observations into a framework for teaching and program organization that is organized around invitations, investigations, and introspection. This study documents tinkering educator pedagogy in ways that will be meaningful to the community of practitioners of maker-centered learning.

In alignment with critical pedagogies (Freire, 1970) and Community Based Participatory Research (Burns, Cooke, & Schweidler, 2011), it is important to conduct research in a way that benefits the organizations that gives researchers the privilege of access to their spaces. This study will also be significant in that it will provide useful data to the Tinkering School as an organization that has kindly afforded me the ability to collaborate with them on a topic we are all passionate about.

**Definition of Terms**

1. **Agency**: the development of an “I-can-do-it” attitude that leads to “feeling empowered to make choices about how to act in the world” (Clapp, Ross, Ryan, & Tishman, 2016, pg. 19).

2. **Agency by Design (AbD)**, a framework authored by Clapp, Ross, Ryan, and Tishman (2016) that was developed through research in classroom makerspaces in a collaboration with Harvard’s Project Zero.

3. **Constructionism**: coined by Seymour Papert, he describes it as stemming “from constructionist theories of psychology, we take a view of learning as a reconstruction
rather than as a transmission of knowledge. Then we extend the idea of manipulative materials to the idea that learning is most effective when part of an activity the learner experiences as constructing a meaningful product (1986, in Martinez & Stager, 2013, pg. 32).

4. **Engagement**: drawing from hooks (1999), this study will use the term to describe learning practices that are active, embodied, and self-actualizing.

5. **Maker-centered learning**: a hands-on approach that centers on creating physical or digital artifacts and supports dispositions such as curiosity, playfulness, willingness to take risks, persistence, resourcefulness, co-learning, optimism, collaboration, a growth mind-set, and a failure-positive outlook on the world (Thomas, 2014 in Clapp, Ross, Ryan & Tishman, 2017).

6. **Makeshop Learning Practices (MLP)**, a framework authored by Brahms and Wardrip (2014) that was developed through research in a children’s museum with an intended audience of 3-10 year old learners and their families.

7. **Making**: from Martinez & Stager (2013), it is about “the active role construction plays in learning. The maker has a product in mind when working with tools and materials” (p. 32)

8. **Making in Out of School Time Settings (MOSTS)**, a framework authored by Bevan, Ryoo, Vanderwerff, Petrich, & Wilkinson (2018) that was developed through research in an afterschool making and tinkering program through a collaboration between the Research+Practice Collaboratory and the Exploratorium.

9. **Tinkering**: from Martinez & Stager (2013), it is “a mindset – a playful way to approach and solve problems through direct experience, experimentation, and discovery” (p. 32)
10. Tinkering Studio’s Learning Dimensions (TSLD), a framework authored by Gutwill, Hido, and Sindorf (2015) that was developed through research in a museum with an audience of learners ages 8 to adult.
CHAPTER 2
REVIEW OF THE LITERATURE

This study occurs at the nexus of three core areas of scholarship: constructionist learning practice, informal learning spaces, and studies of student empowerment. Constructionist learning is a crucial starting point for grounding my research because it is a foundational element of tinkering pedagogy. Learning theory for student outcomes helps to shape educator practice. Informal learning environments have unique affordances and challenges beyond traditional classrooms, which also play into educator curriculum development, teaching style, and goals. These pedagogical and environmental aspects work in concert to foster an environment that supports student empowerment, as evidenced through demonstrated engagement, collaboration, and self-confidence. This review of the literature will attempt to address major themes and issues in each of these topics from a wide pool of sources and distill down the most relevant concepts.

Constructionist Learning Practices

The majority of literature around constructionist learning focuses on individual makers as learners and the mindsets, dispositions, and approaches necessary for success (Peppler, Halverson, & Kafai Eds., 2016b; Honey & Kanter Eds., 2013) or on the physical environment in which maker-centered learning takes place (Peppler, Halverson, & Kafai Eds., 2016a). With the theoretical framework on constructionism presented in the previous chapter in mind, we transition to how they are manifested, supported, and identified in maker-centered learning environments. One of the main ways educational researchers studying making and tinkering have used to organize thinking around learning in these environments is through the development of frameworks to identify what learning looks like through the creation of objects and artifacts. The following frameworks were developed based on research in a variety of settings: formal classrooms, an afterschool program, a children’s museum designed for learners ages 3-10, and a
museum tinkering space focused on learners ages 8 and up. Though this seems like a disparate set of circumstances, a key goal of maker-centered learning is to blur lines between formal and informal education (Halverson and Sheridan, 2014) and the intended audience for these frameworks is broad (Clapp, Ross, Ryan & Tishman, 2016; Brahms & Wardrip, 2014); therefore, they can be analyzed as a collection of texts to draw out common themes of what structural supports educators can enact to support maker-centered learning and identify what key characteristics indicate what that learning looks like in these spaces. In these frameworks, I propose that there are three key themes that surface which support and demonstrate learning with constructionist pedagogies, and can be tied to critical and humanizing pedagogies as well. These learning environments support: *redefining teacher/student relationships*, *creating personally meaningful objects and artifacts*, and *valuing embodied approaches to learning.*

In order to discuss these frameworks deeply, yet concisely, I will use the following naming conventions in the analysis below:

- **Agency by Design (AbD)**, a framework authored by Clapp, Ross, Ryan, and Tishman (2016) that was developed through research in classroom makerspaces in a collaboration with Harvard’s Project Zero.

- **Makeshop Learning Practices (MLP)**, a framework authored by Brahms and Wardrip (2014) that was developed through research in a children’s museum with an intended audience of 3-10 year old learners and their families.

- **Making in Out of School Time Settings (MOSTS)**, a framework authored by Bevan, Ryoo, Vanderwerff, Petrich, & Wilkinson (2018) that was developed through research in an afterschool making and tinkering program through a collaboration between the Research+Practice Collaboratory and the Exploratorium.
• **Tinkering Studio’s Learning Dimensions (TSLD)**, a framework authored by Gutwill, Hido, and Sindorf (2015) that was developed through research in a museum with an audience of learners ages 8 to adult.

*Redefining Teacher/Student Relationships*

In maker-centered learning environments, the term “facilitator” is often used in lieu of teacher (Dougherty, 2016). Teacher, while a useful term, can also have connotations of hierarchy in a learning environment as the keeper of knowledge who controls what students can and cannot learn. In each of the frameworks, that conception of teaching is upended. Educators, facilitators, and teachers are still highly involved in student learning, but in a way that is collaborative and student-driven. AbD describes how teachers can design activities to facilitate student collaboration, encourage co-inspiration and co-critique, redirect authority, and promote knowledge-sharing (Clapp, Ross, Ryan, & Tishman, 2016). MLP sees seeking and sharing resources amongst learners as an indicator of learning (Brahms & Wardrip, 2014). Similarly, the TSDL includes a section on “social scaffolding” which posits that requesting and offering help and building on others’ ideas are evidence for learning (Gutwill, Hido, & Sindorf, 2015). MOSTS places learning in a social and emotional context, and calls out that collaboration, teaching one another, and remixing others’ ideas as valuable (Bevan et al., 2018). In each instance, the frameworks point to how teachers are not the only resources in these spaces; students are encouraged to learn with and from each other. The learning that is shared can be conceptual (as with specific STEM knowledge) or technical (such as sharing how to use a tool).

*Creating Personally Meaningful Objects and Artifacts*

In maker-centered learning, creating something is a given, be it a physical or digital outcome. Some even critique the focus on product over process as a shortcoming of making.
What sets these frameworks apart is how they focus on the meaning behind the objects and why students are creating them. Whether it’s connecting projects to personal interests and experiences (Bevan et al., 2018), setting personal goals and posing problems (Gutwill, Hido, & Sindorf, 2015), exploring ideas that are learner-driven and represent the interest and identity of the learner’s pathway (Brahms & Wardrip, 2014), or expressing ownership over the process of making a personally meaningful object for oneself or one’s community (Clapp, Ross, Ryan, & Tishman, 2016), these frameworks all point to how maker-centered learning can draw out students’ interests and incorporate them into authentic learning. Valuing what students bring to making experiences is not an add-on, it’s integral to their learning experience and is a humanizing practice that makes space for students’ emotional and social contexts. Aesthetics and narrative content are also equally valued as part of the making process. AbD points to opportunities for learners to bring resources from their lives outside of the making space such as their communities (Clapp, Ross, Ryan, & Tishman, 2016) and TSLD calls out drawing from personal prior experience (Gutwill, Hido, & Sindorf, 2015); making curriculum is permeable and students can bring prior knowledge that is relevant to their lives.

*Valuing Embodied Approaches to Learning*

A hands-on approach to learning is central to maker-centered learning. AbD points to access to a variety of tools and materials as a key support for making connections and deepening learning, and that tools and materials can even function as a teacher in the space as students learn from their interactions with these items (Clapp, Ross, Ryan, & Tishman, 2016). MOSTS states that responding to physical feedback from materials indicates that learners are showing initiative and intentionality (Bevan et al., 2018). Furthermore, the framework makes correlations between using materials in novel ways and expressing joy and delight as both being related to creativity.
and self-expression. Similar to MOSTS, the TSLD framework also notes that seeking and responding to feedback indicates learning, and adds that anticipating outcomes of tests with tools and materials is a further learning indicator (Gutwill, Hido, & Sindorf, 2015). MLP is the framework that is perhaps most tied to embodied learning; almost every learning practice relates to tool and material use (Brahms & Wardrip, 2014). Where it differs is in the ways it extends this idea to show how learners can truly develop fluency with making over time. This hands-on approach to learning relates to ideas of engaged pedagogy (hooks, 1994). Learners are not disengaged from their bodies, and instead are acutely aware of their actions and the impact they have on the objects they are designing and the community they’re interacting with. hooks describes the ways in which the idea of fun and excitement can be looked down upon in traditional education, even to the point of being seen as “disruptive to the atmosphere of seriousness assumed to be essential to the learning process” (p. 7). In engaged pedagogy, joy of learning (in this case, tool use) is a necessary and central part of the process.

These frameworks have proven to be a useful tool in the field of constructionist pedagogy in both formal and informal learning contexts. Chi, Dorph, and Reisman (2015) cite both TSLD and MLP in their study on the impact of museum-managed STEM programs in out of school settings. Similarly, Hsu, Baldwin, and Ching (2017) look to AbD, MLP, and TSLD as sources for identifying learning through making as a current trend in technological education. Due to the recent publication of MOSTS it is cited less frequently in the literature, but it has been presented publicly at the Association of Science and Technology Centers annual conference (Kali, Braafladt, Heroman, Roque, Meyer, & Singh, 2018) in discussing tools for training volunteer educators in museum learning environments.
In conclusion, these frameworks can be useful tools for educators in maker-centered learning environments in how they define techniques to support and identify learning through making. They also are thematically linked in the ways they recognize redefining student/teacher relationships, creating conditions to make objects that are personally meaningful, and valuing embodied learning which are all innovative approaches to supporting learners. Readers can make inferences to connections to critical and humanizing pedagogies in these texts, but the relations are not overtly made. An avenue for potential future research would be developing a learning framework for maker-centered education with an explicit focus on teaching and facilitation practices that support learners’ critical consciousness in ways where the making is culturally relevant, and identifying what behaviors indicate learning is taking place with these goals in mind.

**Informal Learning Spaces**

This section will provide an overview of three common informal learning environments. It will describe what these environments look like, illustrate the types of learning that can take place, and highlight the affordances and challenges of each. Key factors that exist across informal, out-of-school learning environments are that involvement is not mandated, students are not held to specific educational standards and regulations, and that participation is often the outcome of leveraging existing social networks and relationships (Bevan, 2017). This section will examine afterschool programs, museums, and libraries as sites of rich STEAM learning.

**Afterschool Programs**

Afterschool programs (ASPs) are learning environments that can take place in both school-affiliated and community-based settings. In comparison to formal schooling, youth enrolled in programs in these spaces are more empowered in the ways they have increased
flexibility in participation and agency in their choice of activity (Tan & Calabrese Barton, 2017). School-affiliated ASPs have the benefit of an existing network of student participants and an established context. There are often student clubs or groups that revolve around a shared area of interest such as drama or science, as well as organized sporting teams. Many times ASP instructors are also school-day teachers who can continue exploring similar themes or ideas during the out-of-school time they have with students. One challenge of school-affiliated ASPs is that because they are often staffed by school teachers, “youth are governed by similar norms and expectations in these informal, after-school organizations as they are during regular school hours” (Tan & Calabrese Barton, 2017, p. 755). In this way, students may feel pressured to show similar interest in STEAM topics as they do in class, rather than leverage the flexibility of afterschool learning to “try on” different identities.

Community-based ASPs have a long history of providing rich programming to youth, particularly those who are underserved in traditional, formal schooling (Vossoughi, Escudé, Kong, & Hooper, 2013; Calabrese Barton, Tan, & Greenberg, 2016). These programs “typically operate in settings where youth already enjoy legitimate membership” (Tan & Calabrese Barton, 2017, p. 755), such as Boys and Girls Clubs and 4H with sites across the nation, or shelters or refugee residential centers which are far more localized. Curriculum and activities in these spaces are often co-developed with youth participants and are largely driven by student interest, sometimes called a “voice and choice” model (Bevan, 2017). STEAM-rich programs can build on this by identifying local needs and using them as a starting point for projects that support learning through making. The community context of these sites fosters life-wide learning. Learning is grounded in social interactions, often takes place over extended periods of time, and covers a variety of phenomena (Visintainer & Linn, 2017). Abstract concepts are made concrete
when they are applied to students’ interests and locally relevant projects. Like school-affiliated ASPs, community-based programs tend to focus on targeted age demographics rather than supporting lifelong learning. In some programs, students who age out of the intended audience and must find alternative ways of engaging, such as becoming a facilitator or program leader, if they want to continue (Calabrese Barton, Tan, & Greenberg, 2016).

Museums

Traditional museums are collections- or exhibit-based institutions with a specific content area or mission-centered educational focus. Museums are sites that support lifelong learning, as the primary audience is mostly adults; Smith and Smith (2017) describe that typical museum visitors have more free time, more education, and are “somewhat wealthier than the population in general” (p. 513). Access to museums is a significant limitation on their impact for some communities. Learning in museums is typically mediated by written labels, tours (both guided and audio), or the museum’s website. Some institutions have docents or offer facilitated programs (like field trips) to deepen learning through personal interactions. Children’s museums and science-technology centers are related designed learning environments that expand both the audience and potential learning impact of traditional museums.

Children’s museums are multigenerational spaces where youth and adult caregivers can engage in hands-on learning though exploration and play. Exhibition and program design are grounded in constructivist practice and “focus attention on learners’ motivations, prior experiences, tacit knowledge and cultural identities” (Brahms 2017, p. 87). Playful approaches to learning are relevant in terms of learners’ cognitive development, but can be hard for adults to recognize as valuable. Adults may also not know how best to support learning through play in these environments.
Science-technology centers and science museums bridge the gap of lifelong learning in museums because their audience includes both youth and adults. The primary goal of these institutions is to spark interest in and curiosity about scientific phenomena, and Sneider (2017) argues that that is possible because these are “places where people are encouraged to touch – to push buttons and levers, arrange lenses, throw their voices across large rooms using a parabolic dish – in a word, to engage with the ‘stuff’ of science and engineering” (p. 678). Similar to children’s museums, the learning is hands-on and engaging, but perhaps less playful in some instances. Physical interactive exhibits are augmented with other learning modalities, such as live presentations, classes and camps, teen programs, theater and planetarium shows, organized field trips, community engagement programs, and teacher professional development workshops to increase the breadth of offerings within and beyond the walls of the institution.

Spaces for STEAM-rich learning through making and tinkering are becoming more common in all forms of museums. These areas are often termed making or tinkering spaces, and host facilitated, hands-on workshops that explore STEAM concepts through the creation of physical artifacts. These are spaces where “youth can engage in a variety of making and tinkering practices, often alongside family members, that leverage novel combinations of physical and digital tools” (Searle, 2017, p. 731) to create personally-meaningful objects. In some museums these workshops are included in the admission price, but at others there are additional fees associated that can be an additional barrier to participation.

Libraries

Public libraries are community-based institutions that provide access to resources and materials, as well as informal educational offerings on a variety of topics. In 2012, public libraries offered over 4 million educational programs to their users (Toro, 2017). Although the
majority of programming is geared towards children’s services, many libraries also have specialty educational offerings for adult audiences as well. One asset of libraries is that as community-based institutions, they have the ability to leverage local expertise to incorporate into educational programs (Anzivino & Wilkinson, 2016). Spaces for informal, STEAM education are becoming increasingly popular in public and university libraries. The exact resources will vary from space to space and be determined by the community’s needs, but generally these workshop areas provide access to digital and physical tools such as laser cutters, 3D printers, woodworking tools, audio recording equipment, and CAD software. Willett (2017) describes that this is a “natural extension of libraries’ traditional role as a provider of educational resources” and is simultaneously also “a new iteration of library programs in which patrons are taught to produce materials rather than simply to consume them” (p. 1). One example of this is the Chicago Public Library’s Maker Lab; this space is geared towards an adult audience and focuses on teaching digital design and production tools, while also “support[ing] CPL’s larger goal of making science concepts and complex problem-solving skills broadly accessible” and providing adults with an “on ramp” to the larger Chicago making community (Saenz, 2017, p. 18-19).

**Student Empowerment as Evidenced Through Engagement, Collaboration, and Self-Confidence**

One of the core affordances of maker-centered learning are the positive impacts it has on students beyond supporting development of STEAM content knowledge. Educators value the socio-emotional learning that takes place as an equally important component of the learning experience. This section will focus on studies that discuss evidence of changes in student engagement, collaboration, and self-confidence in a variety of science learning environments.
In their 2018 study, Blackley, Rahmawati, Fitriniani, Scheffield, and Koul present their findings on the impact of a one-day, hands-on STEM experience using what they call a Makerspace model. The study took place at four schools in North Jakarta, Indonesia with 291 Year 5 and 6 primary school students and was facilitated by pre-service teachers (PSTs). Researchers supported the PSTs to lead an activity called Wiggle Bots that involves making a contraption built from a cup and felt-tipped markers that uses an offset motor and battery to make it move and draw patterns. They reported that making Wiggle Bots effectively supported “student engagement, self-confidence and scientific knowledge” (p. 29). Students were surveyed following the building session as the primary method of data collection. One major indicator of engagement was that 98% of students enjoyed participating in the activity. Furthermore, a high percentage of students agreed that working in a group with a PST mentor was helpful for completing their project successfully and that “working together stimulated student collaboration and communication skills” (p. 31). The project also supported the development of self-confidence, and afterwards students “felt confident they could make other Makerspace artifacts” (p. 32) knowing that collaboration was an important part of that process.

One significant limitation of the study the researchers noted was an “apparent lack of creativity” in the students that the researchers see as stemming from the “initial instruction given to them [the students] in their groups by their pre-service teacher mentor” (p. 37) that encouraged copying the exemplar design rather than encouraging students to make their own designs. Early in the report the researchers state, “Whilst there is some capacity for modifications to the basic design, the goal is for each maker to end up with a complete and workable artifact” (p. 22). This focus on a working final product over the process of creating it could be interpreted as one factor that has the potential to limit student creativity. More information could be given on how the
PSTs were trained to facilitate this activity, and additional research could be done on how that training impacts students not only to gain confidence and practice collaboration skills, but also learn to exercise individual ideas rather than copy from a known-answer solution.

A thematically related study was done in Singapore on the impact of student learning through Collaborative Science Inquiry (Sun, Looi, & Xie, 2017). In this study, learning on a Grade 7 biology unit was structured to allow for different forms of online collaborative work through several inquiry-based phases. In addition to supporting students to practice the scientific method, the unit also “offers various opportunities for students to discuss solutions, co-construct knowledge, assess artifacts and interact with teachers” (p. 248). Teachers were also encouraged to “play flexible roles” beyond simply instructing students so that the learning environment was more constructivist in nature. Students engaged in practices such as discussing initial ideas, negotiating tasks and division of work, reviewing peer answers, and co-writing while also engaging in scientific modeling and data collection. Researchers found that students’ “conceptual understanding and collaboration are mutually improved and enhanced” through participation in an inquiry-based, collaborative model (p. 258). Although this study focuses on a digital platform for communication and collaboration, it can be extrapolated that inquiry-based science learning would support similar (or possibly more) socio-emotional skill development with in-person collaboration.

As the previous two studies show, the role of the educator has deep impacts on students’ engagement and ability to collaborate. Educator flexibility can allow for students to construct their own understandings of scientific phenomena through peer-to-peer collaboration, yet at the same time limited educator training can have unintended consequences such as stifling student creativity. Maclellan’s (2014) review of the body of literature regarding self-confidence
addresses the specific question of what pedagogical practices support learners’ development of this trait. Working from the definition that self-confidence is “the individual’s impression of his/her competence in a specific domain, context or situation” (p. 62), the article points out several necessary factors for healthy growth. Foremost, the role of the teacher is crucial; they must be genuine and willing to engage learners in constructive discourse and self-reflection on their own skills. They must also have an appreciation for the nuanced ways self-confidence can manifest itself in student behavior.

Maclellan points to the importance of emotional wellbeing as a grounding factor for developing self-confidence. Additionally, teachers who build on what is already positive in their classrooms are more effective at supporting this trait. Collaboration, whether in learner-learner or learner-teacher interactions, is also significant. The research finds that “curriculum organization…which promotes the active and voluntary sharing of knowledge is one mechanism through which students can strengthen their internal locus of control and, thereby, their confidence” (p. 66). Educators can also foster a culture that success is based on effort rather than fixed internal talent. This is especially important in STEM fields, where there is a “need for teachers to be pro-active in countering stereotypical perceptions of insurmountable difficulty and resulting loss of confidence when studying these subjects” (p. 67). The article concludes with a list of specific recommendations for educators drawn from the previously listed principles. The findings presented in this article, in conjunction with the previous two studies, work together to demonstrate the dynamic and interconnected relationship between student engagement, collaboration, and self-confidence, and how in conjunction can lead to an environment that enables student empowerment.
Summary

At first glance, the topics of constructionist learning theory, informal educational spaces, and student empowerment may seem disjointed, but upon further inquiry, they are actually deeply interrelated. Frameworks designed to identify learning in constructionist spaces show that redefining the educator-learner relationship, creating personally meaningful artifacts, and valuing embodied approaches are lenses through which educators can understand the learning that takes place. Informal spaces such as museums, libraries, and afterschool programs are well suited to this approach to teaching and learning because of their flexibility and focus on following learners’ individual paths. Through hands-on participation in STEAM-rich activities in community-oriented settings, learners are well equipped to be highly engaged in their own learning, practice collaborative approaches, and develop self-confidence. Woven through all this is the theme of educator pedagogy, which defines what activities are done, how the environment is set up, what tools and materials are available for use, how group interaction is configured and supported, and what goals for learning are emphasized. The following chapter will draw on these themes and present a case study of what they look like in action.
CHAPTER 3
RESULTS

The purpose of this thesis is to examine, document, and identify educator pedagogical practices in a tinkering environment that have demonstrated impacts on student learning and experiences. Through establishing educator definitions of tinkering and learning their primary pedagogical goals, I aim to accurately represent how these ideas are acted out in practice. As a critical researcher whose goal is to participate in a reciprocal relationship with the partner organization, an additional goal is to develop a research-based tool describing tinkering educator practice in informal learning environments. The intention is that this tool can be useful to both the field of constructionist educators as well as the partner organization.

I conducted an ethnographic study of tinkering educator practices in an informal learning environment at a program serving elementary-aged, low-income youth of color over a three-month period. The dataset for this study draws from two sources – staff interviews and ethnographic fieldnotes. The five 30-minute educator interviews were conducted over a six-week window with staff from both the Tinkering School (Michael, Rampage, and Steven) and San Francisco Boys and Girls Club (Leslie and Aziz). Nine fieldnote observations were conducted over the three-month semester of programming. These sessions were held at two different sites and projects covered two different topics. The Mission Boys and Girls Club traveled to Brightworks School for Tinkering School sessions that focused on making human-scale carnival rides; one group made a gravitron spinner that could carry four passengers, and two groups made rocket swings that could each carry two passengers. The Willie Mays Boys and Girls Club met onsite at their clubhouse and the project topic was vehicles you can ride and steer; there were

1 All educator and student names referenced in the following analysis are pseudonyms.
three groups who made uniquely designed gravity-powered go karts. Tinkering educators held program with each site once per week.

*Image description: One of two rocket swing designs*
Image description: Youth and TSCs pose with three completed gravity-powered go kart designs

Image description: Youth and TSCs pose with the completed gravitron spinner
“Growing and learning with kids…to make something bigger than ourselves”:

**Tinkering Educators Define Their Practice**

Before embarking on an analysis of the pedagogical practices of tinkering educators, I first present how educators define tinkering and what their primary goals are. Articulating the educators’ personal definitions of tinkering and their pedagogical goals is a key first step in addressing my research question of identifying pedagogical practices because these definitions and goals shape how programming is developed and implemented. Many of the educators’ answers parallel Martinez & Stager’s (2013) definition that tinkering is “a mindset – a playful way to approach and solve problems through direct experience, experimentation, and discovery” (pg. 32). Tinkering School collaborator Rampage described tinkering as “a way of engaging with the world” using a “growth mindset,” and that “tinkering is a lifelong practice” (interview, 9/21/18). All the educators stressed that problem solving is a core part of the process, and they go beyond Martinez and Stager’s definition to add that making mistakes is a core component of that process. Steven explains tinkering is about “having an idea and finding out ways to make it work and learning from the ways that it doesn’t work” (interview, 10/19/18), and similarly Aziz describes that as you “make and create” you “always learn from your mistakes” (interview, 10/26/18). Both Michael (interview, 9/17/18) and Leslie (interview, 10/4/18) include that tinkering is hands-on and “a very tactile experience” (Michael). The themes of making mistakes and engaging in hands-on experimentation will be revisited later in the analysis as core components of tinkering educator pedagogy.

The Tinkering School program has four main goals that underlie its philosophy and practice: collaborate and make new friends, try harder than usual, make mistakes and learn from them, and build something bigger than ourselves. They are posted on signage as a reminder and
are placed prominently in the work area at the early sessions (fieldnotes 9/25/18 & 10/4/18).

When asked in their interviews what their primary goals are as educators in the space, Michael explicitly discussed the Tinkering School goals and the other educators referenced them more obliquely. Evidence from the dataset shows that the educators find many and varied ways to address these goals through pedagogical practices. When articulating their goals, several educators mentioned that it was important to be present with the youth and maintain a learner’s mindset. In Steven’s words, she\(^2\) says:

> The biggest goals I’ve set for myself are to really to give them all of my attention, to be as present as possible, and in the moment as possible…I feel like I’m very much at the kids’ level and experiencing it with them, which is part of why I think the Tinkering School is such an amazing and different environment and why the philosophy is also really exciting for me because it allows me to continue to grow and learn with the kids.

Steven’s description of “experiencing it with them” is a pedagogical tool for deconstructing the teacher-student hierarchy. She articulates a practice of being willing to co-learn alongside youth. Analysis of the data will show that the intention of being present and having flexibility in the moment manifests itself in practice.

Michael, Steven, and Leslie all mentioned that an important pedagogical goal of the program is that it provides access to tools and materials the youth may not have used before. This hands-on participatory access relates to the educators’ previous definition of what makes something tinkering, and is central to how the program is structured pedagogically. Leslie’s answers were unique in that she framed this access in terms of educational equity:

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\(^2\) Steven is a female-identified facilitator who uses she/her pronouns.
I think an important thing and then coming to our club, you can see the demographic, it's mainly African-American and Latino children. I think it's important for them to get this opportunity. Right now, they're going to schools in and around this neighborhood that are forced to be focused on preparing for a test. Most of the schools that these kids go to have lost funding in the past year due to not meeting state standards and that means they don't get programming like this. They don't get the opportunity for this stuff and they especially don't get it in a neighborhood like Hunters Point where we're lacking resources. I think it's such an amazing opportunity for them that there's equity in the programming that's offered because they deserve some programming just as much as a group of kids in Pacific Heights. For me, it's really important that we have programs like this because it's just introducing them to different things. (10/4/18)

She shared that a student told her “they don’t do science in school,” and that Tinkering School programming helps to fill that void. Hunters Point is a traditionally African American and working-class neighborhood in San Francisco. As demographic trends shift, there are now more Latinx and Pacific Islander residents as well. Schools serving working class youth of color tend to have a more rigid curriculum focused only on topics related to high-stakes state testing, and teachers are limited to providing scripted curriculum that does not always address students’ needs and personal interests (Lipman, 2011; Kumashiro, 2012). The partnership between Tinkering School and the B&GC affords access to elementary STEAM programming that is absent in the public school system that these youth attend. Additionally, Leslie states that the adults in the program are another resource because the youth are able to “build new adult relationships with people who are good role models” and that “they’re bringing in something bigger than just ‘here’s facts.’ It’s teaching the kids how to interact with other people in a space
and teaching social interaction and how to work with others, and for us, that’s so important.” Access manifests itself in many ways in the program. It becomes about more than just tools and materials, but also ideas and ways of being and becoming (Petrich, Wilkinson, & Bevan, 2013) that are STEAM-rich and go beyond what is available in the students’ traditional classroom environments.

A Pedagogical Tinkering Framework: Invitations, Investigations, & Introspection

Analysis and reflection on the dataset shows that tinkering educators’ pedagogical practices strongly support student engagement with real tools and materials, collaboration with fellow youth and adult facilitators, and development of self-confidence. The specific teaching practices can be organized into a pedagogical framework I have developed, and fall into three main categories: 1) invitations to participate, 2) investigations into phenomena, and 3) introspection on process (Table 3.1). These categories are not linear; they are visited and revisited upon throughout the sessions. Invitations to participate are how youth are welcomed into and supported throughout the building sessions. Investigations into phenomena are the ways educators facilitate inquiry-driven exploration the youth engage in while building. Introspection on the process describes how the educators encourage reflection during and after the program sessions. Each phase of facilitation supports the student learning and development outcomes listed above. The following analysis will define each of these practices and provide examples of what they look like in action.
Table 3.1: A Pedagogical Tinkering Framework: Invitations, Investigations, and Introspection

**Invitations to Participate**

These are the many and varied ways the Tinkering School Collaborators (TSCs) provide a welcoming and safe environment in which to participate. Invitations are present in the physical environment and the intangible ways the educators interact with youth. This can include the ways educators address both the physical and emotional needs of the participants. Evidence of invitations to participate took several different forms in practice. One baseline way that youth were welcomed to the program was through addressing physical comfort by providing snacks at every session and letting students know “they can always get water whenever you need it” (fieldnote, 10/9/18). Sharing food helps to build community and allows the students to focus so
they’re not distracted by being hungry. Similarly, stating permission to take water breaks gives the youth autonomy to elect that option when they need it. TSCs attend to physical safety by helping students with long hair to tie it back when using tools that spin (fieldnote, 10/16/18) and reminding them to wear eye and hearing protection when using tools (all sessions). TSCs also model attention to physical safety when testing youth-built projects by being the first ones to ride in or on them to ensure that they’re structurally sound (fieldnotes 11/13/18 & 11/15/18). The pedagogical concern for physical safety and comfort has positive impacts students’ engagement hooks, 1999). For example, when using power tools, the attention to physical safety helps to overcome initial nervousness about tool use and allows students to express excitement and encourage others. When using the chop saw, students were highly engaged and reminded their friends of safety procedures, such as the “ready call” before initiating tool use (fieldnote, 9/24/18). Furthermore, they expressed their confidence in what they had just learned by mirroring the role of the facilitator for their peers. The learning taking place is embodied and self-actualizing in the ways the students are fully present and actively excited about their personal growth as individuals and as a collective.

Beyond attention to physical comfort, TSCs also support emotional safety and provide intellectual invitations to participate. Asking questions is one of the main pedagogical techniques for this. In traditional classroom environments, the role of questions is often to quiz for regurgitation of knowledge or prompt compliance. In the Tinkering School, the primary role of questions is to draw out students’ ideas or to engage with problem solving. The Opening Circle is a daily program ritual that serves to ground the community in a welcoming moment and often begins with an introductory question that ranges from “Share something about your day” (fieldnote, 10/9/18), to design recaps from the previous week (fieldnote, 10/16/18), to asking
“What are our goals for today?” (fieldnote, 11/8/18). The first session’s Opening Circle is especially significant because that is the moment when they discuss the Tinkering Studio goals and establish Group Agreements. Although there are some pre-determined safety-related agreements, the TSCs ask questions to get ideas about what agreements should exist from the group, and then build off suggestions from the youth by mirroring their language and rephrasing them to meet those safety standards. This process sets the tone that at Tinkering School there will be many opportunities to participate and that the process will be collaborative and group-driven.

Even in moments of conflict, rather than telling youth what to do, TSCs use questions like, “What can we do when we’re having a challenge with someone?” to scaffold the solution from a student-led perspective (fieldnote, 10/4/18). This is an explicit invitation to participate in setting the tone and culture for engagement and collaboration in the program.

The impact of these invitations to participate is evidenced by high levels of engagement (hooks, 1999) in the youth. Students demonstrate this through their desire to join the program, consistent participation, and enthusiasm for building. As B&GC staff member Leslie states, “They love it. Every week it’s kids asking, ‘When’s tinkering coming? When’s tinkering coming?’” (interview, 10/4/18) and during a program session Cyrus said, “I wish I could come to Tinkering School every day! Or, at least on weekends” (fieldnote, 11/13/18). The joy of learning is clearly present and is a strong example of engaged pedagogy in action.

Investigation into Phenomena

With a primary goal of the program being ‘build something bigger than ourselves’ educators in the space find many ways to support students’ investigations into phenomena. This requires creating conditions that allow for hands-on experimentation with real tools and materials. There are opportunities for instant feedback on your process – a cut might come out
crooked, a screw might not go in all the way, or two pieces you thought were attached might fall apart. Tool training happens at the first and second sessions, and is the first opportunity for youth to engage with the foundational processes for building. During drill training, collaborator Rampage encouraged her group to look to Eva, a returning participant, for tips on techniques for using the drill when they were struggling to drive in a screw (fieldnote, 9/24/18). The pedagogical technique of redirection of authority simultaneously deepened students’ investigations into the materials, while also supporting collaboration and the development of youth self-confidence by positioning Eva as an expert. Students picked up on the pedagogical expectation that expertise can come from anyone in the space. For example, when Francisco was experiencing a similar challenge with using the drill, Drake stepped in and offered him a suggestion that helped him improve his skills (fieldnote, 10/9/16).

A collaborative moment took place between Tristan, Xander, and Marco centered on their exploration of building the structural spokes and wheels for the gravitron spinner^3^ (fieldnote, 10/16/18). Tristan and Xander were excitedly engaged with drilling large holes for the wheels, and at one point Tristan called out to B&GC facilitator Aziz, “Look at us!” to show how proud he was of the holes they were making. Meanwhile, Marco noticed that as they added wheels, it changed the angles of the structural spokes he was working on. He used a tape measure to investigate the difference in height between the outer edge and the center and discovered a 3” difference. He expressed a concern they would have to add something to the center to make it taller. As they worked together to add all eight wheels, Marco noticed that the gravitron was level again, and he exclaimed, “I get it now! It’s because there was only one at the beginning!” Rampage was present for this investigation and allowed them to work out the challenge of

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^3^ A large-scale wooden carnival ride that spins and can hold four passengers.
placing all eight wheels and supporting the structural spokes. Her trust allowed them to work independently and heightened their engagement with building and development of self-confidence as they came up with solutions to perceived challenges.

De’Andra and Jackson had a similar experience of getting feedback from material phenomena as they investigated building (fieldnote, 11/8/18). They wanted to add a plastic head protector to their vehicle, but the screws they had were too long and would poke through the wood unsafely. Michael suggested they use a nut as a spacer, but they still struggled to drive the screw in. De’Andra asserted that they needed a second piece of wood instead. She came up with the solution of sandwiching the plastic between the back panel and a scrap piece of wood, then used a clamp to hold it while she and Jackson finished attaching it with screws. This moment shows that their desire to attach the head protector kept them engaged with building in the face of challenges, they collaborated to finalize their solution, and that De’Andra had the self-confidence to discard the suggestion from an educator and come up with her own solution instead. From a pedagogical perspective, TSCs practice this flexibility in offering scaffolding and support while also co-learning alongside students (interview with Steven, 10/19/18).

**Introspection on Process**

Reflection on process both in the moment and following each session is highly emphasized. Educators model this practice with youth and with each other. Returning to the theme of questions as a pedagogical tool, the reflective process centers on thoughtful questions asked at key moments in the building process. For example, Steven facilitated her rocket swing group by asking a series of questions to draw out their ideas on how big each rocket should be and how they want to hang the rockets from above (fieldnote, 10/9/18). The group decided that the rocket should have 3’x6’x1.5’ dimensions. When prototyping it at that scale, they were
surprised to see how large that actually is, and Drake announced, “It’s too big!” Steven affirmed the group’s feelings by saying, “It’s bigger than we realized” then asked, “Is this how we want it?” This moment takes what could be construed as a mistake and reframes it as an opportunity for students to collaboratively act on their agency and decision-making. As a collective, they decided that the larger design would be acceptable because then more people could ride on the swing at a time. A simple question from a facilitator provided the reflective intellectual space for the students to choose how they would follow through on their ideation and design process.

From the data, it’s clear that the youth in the program are observing, reflecting on, and internalizing the teaching practices of the TSCs. In one session, Rampage suggested that Gloria and Marco work together to attach some pieces of wood to their gravitron spinner and said, “Gloria, you can drill and Marco can follow behind you and screw” (fieldnote, 10/16/18). After they successfully completed their part of the project, they were ready to move on to the next step and Gloria asked the group, “Who’s gonna drill and who’s gonna help do the screws?” Her question mirrors Rampage’s facilitation earlier in the session. This moment shows she has grown in confidence to take on leadership of her group and feels prepared to facilitate future collaborations.

Reflection is also built into the structure of the program for both the whole group and the TSCs themselves. Closing Circle takes place at the end of most sessions and is an opportunity for the youth to share their process from the day. Reflection on mistakes and appreciations for others are two of the prompts TSCs often use. By the second to last session on 11/6/18, Tristan, unprompted, contributed “I learned from a mistake today” and went on to describe it. Drake followed that by asking, “Can I give an appreciation?” The continued pedagogical practice of asking reflective questions is designed into the culture of the program, and students take
ownership of these ideas and take initiative to express them. It takes confidence to willingly discuss making a mistake in front of a crowd, and the desire to give an appreciation shows both engagement with the group and an affinity for collaboration.

The TSCs model this same exercise for themselves. They engage in praxis conversations following each program session. They use a Delta/Plus framework to review what went well and what could possibly be changed for future sessions. They discuss topics like environmental set up concerns, for example was it helpful or distracting to have the rocket swing already hanging when the students arrived (fieldnote, 11/6/18), as well as larger activity design observations and concerns about interpersonal dynamics within the group. These are also important moments for the TSCs to revisit their pedagogical goals for the program. In one conversation, Steven expressed a concern about the pace her group was working at, and Michael reassured her saying, “with the pace, it takes recalibration of our own hopes and expectations” (fieldnote, 10/16/18).

The concept of “recalibration” voices the pedagogical intention of letting youth be the leaders of their own experiences.

The final session for each program is structured in two parts: a final build and a community showcase for family and friends (fieldnotes 11/13/18 & 11/15/18). Students are able to share what they made with their families, show what they’re most proud of, and welcome them to try out their designs. The final design of the rocket swings were two 3’x6’ bases with different covers and tops that hung from a beam in the Tinkering School ceiling and swung more than 15 feet back and forth. As the youth tested and demonstrated their rocket swing, Francisco’s mother marveled, “¿Lo construyeron los chiquitos? ¡Guau!”4 (fieldnote, 11/13/15). Similarly, during Opening Circle Henry exclaimed, “My parents are coming!” and was excited to show his

4 Did the kids build it? Wow!
mom how he could steer the vehicle his group designed. Peer to peer sharing is another facet of this community-based reflection. Heidi proudly showed off her vehicle to a friend. She focused on explaining how it has a seat where “you can sit and relax on it” because that was one part of the vehicle she had full ownership over (fieldnote, 11/15/18). Having the ability to share their process with their wider community broadens engagement (hooks, 1999) by making ties to familial networks and affords the opportunity to express pride and ownership in their creations.

**Summary**

There are several pedagogical strategies and techniques used by TSCs that work to support student engagement, collaboration, and self-confidence. They offer invitations to participate by creating an emotionally and physically safe and welcoming environment. They ask questions to draw out student ideas, affirm the questions and feelings of the group, and model safe building and testing practices. Investigations into phenomena are facilitated through direct and early access to tools and materials. TSCs allow youth to explore their ideas independently and understand that mistakes and challenges will be an inevitable part of that process. They also practice flexible thinking and facilitation so that youth can have ownership over developing solutions. Introspection on the process is structured into the pedagogical design of the program for both the youth and educators. Closing Circle and Delta/Plus conversations create a culture of reflective thinking. Facilitated questions throughout the building process also promote students to practice collaborative decision-making and agency. The final showcase gives space for students to reflect on what they’ve accomplished with their wider community. The pedagogical designs that intentionally foster invitations, investigations, and introspections support student outcomes of collaboration, self-confidence, and deep engagement with building.
CHAPTER 4
DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

Discussion

This study synthesizes the fields of constructionist learning practice, informal educational spaces, and studies of student empowerment through the focus on the impacts of educator pedagogy. Program structure and design has strong connections to research-based frameworks for constructionist learning practice. Evidence shows that TSCs use pedagogical practices such as redefining teacher-student relationships, supporting the creation of personally meaningful objects and artifacts, and valuing embodied approaches to learning which all have positive correlations with STEAM-rich learning (Clapp, et al., 2016; Brahms & Wardrip, 2014; Bevan & Ryoo, 2017; Gutwill, Hido, & Sindorf, 2015). They do this through a program that is structured to offer invitations to participate, support investigations into phenomena, and foster introspection on the process. This pedagogical arc is significant in the ways it supports student engagement, collaboration, and self-confidence.

Students in the program utilize “voice and choice” (Bevan, 2017) to elect to participate in the Tinkering School program, which demonstrates their high levels of engagement. STEAM-rich learning outside their formal classroom context evidences the field-wide trend that community-based ASPs are able to organize rich programming for youth who are underserved in traditional, formal schooling (Vossoughi, Escudé, Kong, & Hooper, 2013; Calabrese Barton, Tan, & Greenberg, 2016). In this informal space they feel free to express intentions and ideas, as well as confidently proclaim that they’ve made mistakes and what they learned from them. Program pedagogy and design leverages the affordances of informal spaces to create a rich environment for learning through tinkering.
Findings from the dataset show that educator pedagogy has significant impacts on student empowerment, which evidences itself through collaboration, engagement, and self-confidence. The hands-on nature of the activities supports engagement, and program design intentionally fosters collaboration. Maclellan (2014) discusses that collaborative program design and an intentional focus on emotional wellbeing have a direct correlation with confidence building.

Through pedagogical invitations to participate and collaborative investigations into phenomena, TSCs affirm this finding through practice. The facilitation is intentionally flexible to allow for student-driven outcomes (Sun, Looi, & Xie, 2017). This leads to a learning environment that is non-hierarchical as educators and youth co-learn side by side. The findings show that students demonstrated collaborative participation, development of self-confidence, and high levels of engagement through behavioral affect and declarative statements.

These findings are significant in that they show intentional pedagogical design and practice are necessary for cultivating positive student learning outcomes in constructionist spaces. Educator practices that allow for student-driven learning help to support engagement and collaboration. Furthermore, educators who engage in their own reflective praxis are prepared and able to revisit their own pedagogical goals and ensure that program design accurately reflects those goals. The act of self-reflection is a cultural practice that can be implemented with youth as well. The organizational framework for pedagogical practice based on invitations to participate, investigations into phenomena, and introspection on process is valuable to the field in that it can serve as a tool for other constructionist educators to reflect on their own pedagogical practice.

**Recommendations**

Findings from the data show that participation in Tinkering School programming is undoubtedly a transformative experience for the youth who participate. They are highly engaged,
excited to work collaboratively, and they develop self-confidence through their tinkering process. That being said, the act of reflective praxis supports continually finding opportunities for growth and development. One possible pedagogical practice that could deepen the impact of participation in Tinkering School for youth is to add an additional and explicitly stated goal of educational equity to the educators’ approach. Projects could not only involve the creation of large-scale mechanical devices, but also involve raising students’ critical consciousness (Freire, 1974). In particular, when facilitating working-class youth of color, it could be beneficial to examine interactions more deeply and reflect on pedagogical practices through the lens of culture and power (Vossoughi, Escudé, & Hooper, 2016). Making and tinkering, as an educational and social movement, has been critiqued in the ways it is often portrayed as being an upper-class, White, and male pursuit, despite the rich traditions of making found in non-dominant cultures in the United States and around the world (Buechley, 2014). Educators may try using existing program structures, like the Opening Circle, to ask youth to describe what tinkering looks like in their families and communities. Questions like, “Who in your family uses tools?” or “What is something you’ve made before?” acknowledge that youth bring background knowledge, history, and familial practices into the space, and that STEM is present in their lives in ways they might not currently make connections to. This practice would build on the idea of Community Cultural Wealth and that, although the youth in the program may not have access to STEM in their formal classrooms, it doesn’t mean their daily lives aren’t STEM-rich (Yosso, 2005). The program already has a strong background in critical pedagogical techniques that lead to transformative learning outcomes, and these recommendations are possible ways to deepen that existing practice.
For the field, findings from this study suggest that constructionist learning through tinkering is a valuable and impactful approach for STEAM education that makes content personally meaningful through the creation of large-scale artifacts. Although time in K-12 schooling for STEM is limited, tinkering pedagogy may be one way to incorporate both meaningful science learning and socio-emotional development at the same time. If tinkering can’t be incorporated into formal classroom time, an informal making and tinkering space accessible to students could be an alternative model. What is crucial is that whether tinkering takes place in a formal or informal setting, thoughtful and reflective facilitation that bears in mind student invitations to participate, investigations into phenomena, and introspection on the process is necessary to afford the most positive outcomes for youth. Policymakers and funders interested in the maker movement and constructionist learning must plan for not only the physical spaces for making and tinkering, but also the ongoing support of staff that are trained to run those spaces and develop meaningful, intellectually-rich activities and programs.

Conclusions

This study concludes that the impact of intentional pedagogical practice to support student learning in constructionist spaces cannot be underestimated. The field has a tendency to focus on student projects and the materiality of environmental design without paying sufficient attention to the educators who conceive of and facilitate those projects. The most significant finding in terms of effective educator practice for supporting student engagement, self-confidence, and collaboration is the role of open-ended questions throughout the building process. A well-timed or well-worded question affords the opportunity to draw out student ideas, foster collaborative interactions, and promote reflective thinking on the overall process of design and building. Questions open a door for student agency and engagement; they allow space for
choice and promote independent action. Youth in these spaces are sensitive to the type of facilitation offered and are able to internalize and mirror those same practices. This develops a reciprocal relationship where adults in the space are trusted guides that initiate investigations, and then allow students to exercise their own agency as they gain comfort and confidence using the tools and materials.

The second most significant finding is that the role of a rich and supportive intellectual environment is a major factor in youth learning. Tinkering School program design asks youth participants to do something big. They are given tools and materials to create larger-than-life size functional mechanical creations. Pedagogical practices present in this environment facilitate towards making these goals a reality. Care and attention are given to creating a physically and emotionally safe environment, which creates space for creativity and rich STEAM exploration. Youth are able to design and create because the activity design and facilitation are purposefully generative, open-ended, and intellectually stimulating.
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Chapter 2: Contemporary Developers of Critical Pedagogy.


