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“How Am I a Maker Making a Makerspace?” : A Focus on Teachers in Practice Self-Authoring as Makers in Constrained K-8 Spaces

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"How Am I a Maker Making a Makerspace?"

A Focus on Teachers in Practice Self-Authoring as Makers in Constrained K-8 Spaces

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A Focus on Teachers in Practice Self-Authoring as Makers in Constrained K-8 Spaces

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Abstract

Although there has been an abundance of empirical inquiry into making in recent years, interestingly, and despite growing interest in the integration of making into N-12 education, little seems to be known empirically about the ways in which teachers are implementing making and creating makerspaces in their own classrooms. Very little direct attention has been paid to 'pioneer' N-12 teachers who are engaging students in making. This gap in the research obscures our understanding of how teachers think about making, how they practice as teachers and makers, and how their school context might influence their teaching and making practices. This multiple-case study asked: In what ways do three K-8 teachers appear to be conceptualizing and implementing making with students? In sum, the three teachers in this study encountered numerous tensions while navigating the contexts of their school, N-12 education, and the Maker Movement as they implemented making in their classrooms. They practiced with a strong sense of agency despite the fact that so many constraints were imposed upon them by more powerful authorities, such as standards-based school reform measures and formal school structures. This in-depth case study contributes new insights into ways in which teachers make decisions about implementing making as a part of their teaching practice and ways in which teachers make use of their agency within the current accountability climate.

Keywords: Maker Movement, making, teacher, self-authoring, history-in-person, agency

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Dr. Reva Jaffe-Walter generously took over as my dissertation committee chair in Dr. Knobel's absence. Despite her own personal loss, she somehow was able to be the world's best

cheerleader during a period that was emotionally wrought for everyone in the TETD program. As I drafted my findings chapters, she provided invaluable input on theory development, and more importantly she helped me feel competent and worthy as a novice academic writer. Her encouraging words kept me going. For this, I will be forever grateful.

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Dedication

This work is dedicated to the friends and family who remained in touch as I withdrew into a world limited mainly to writing my dissertation and caring for a parent who suffered from dementia. In particular, I would like to recognize the New Jersey women's flat track roller derby community that, despite my leave of absence from derby to focus on my dissertation and pandemic-related roller derby shutdowns, always kept the porch light on. The roller derby community's unconquerable and inclusive social spirit helped keep me from becoming dangerously isolated. I felt assured that "once a derby girl, always a derby girl."

Contents

Chapter 1: Introduction

The aim of this dissertation study was to shed light on how three K-8 teachers were thinking about and engaging their students in *making*—or producing items while using an iterative design or less formal trial and error process—and adjusting their practices to include such *maker* activities in their respective classrooms. Informed by Discourse theory (Gee, 2014), self-authoring theory (Bakhtin & Holquist, 1981), history-in-person theory (Holland et al., 2001) and grammar of schooling theory (Tyack & Tobin, 1994), the purpose of this study is to understand the interchange between the practices of the technology-influenced do-it-yourself community known as the Maker Movement and the field of N-12 education. As such, this study focused in depth on three K-8 teachers and their school contexts. I used a multiple case study design (Yin, 2017) to provide a sense of what makes each case (teacher and context) distinct and cross-case analysis to seek patterns across the three cases. Interviews and field notes served as my main sources of data, and I used an iterative coding process. As a result, I was able to identify factors that could possibly influence teachers' maker practices in schools and suggest ways in which school policies, practices, and resources might either support or constrain teachers' implementation of making.

Background to the Study

My interest in teachers who engage students in making began with an interest in 3D printing. The business school at my university had posted a flier around campus inviting students to enroll in a 3D printing class targeted to entrepreneurs. As a female artist with no 3D design or engineering-related skills, I immediately saw the potential in 3D printing as an empowering and potentially lucrative skill set for women, children, and others who, for one reason or another, would or could not pursue an engineering degree yet wanted to be able to design and produce

their own items. As I looked more closely at 3D printing in school settings, I found that the learning process students engaged in resonated with me as an elementary educator, and this inspired my more general interest in making. I also noticed that it seemed to be more often individual teachers who were introducing 3D printing and making into the school curriculum rather than collaborating groups of teachers or administrators. I became increasingly curious about what motivated these teachers and how they were able to add making to a K-8 curriculum that was growing increasingly narrowed and regulated by standards and accountability-based education reform measures.

Making in schools. There are a variety of reasons why The Maker Movement and its associated maker practices could be attractive to teachers. To begin, maker practices emphasize processes of defining problems and designing solutions, and these areas of focus align with Next Generation Science Standards (Martin, 2015; National Science Teachers Association, 2014), the most recent iteration of national STEM content standards. In addition, it seems that STEM educators appreciate the potential for inquiry-based making projects to intellectually engage students and encourage them to pursue STEM fields (Agency by Design, 2015; Bevan et al., 2014; Obama, 2009). Similarly, school librarians who have turned sections of their libraries into makerspaces seem to value making's emphasis on participatory and student-led learning (Fleming, 2015; Preddy, 2013). Fine and performing arts teachers recognize the potential for arts courses and after-school arts activities to provide students with important "STEAM" skills, such as design, communication, and creative planning. The arts have also been identified as potential STEM access points for students who might otherwise exhibit little interest in STEM subjects (Jolly, 2014). The U.S. Department of Education has issued federal funding to spur the creation of rigorous K-12 STEM programs in several states through its Race to the Top program (U.S.

Department of Education, 2016) and, more recently, a few colleges and universities across the country have begun accepting maker portfolios as supplemental application materials for admission (Lindsey & DeCillis, 2017).

Little is known about how non-STEAM and elementary classroom teachers think or practice in regard to making in school. A few studies have focused on preservice preparation and in-service professional development in making (e.g., Cohen et al., 2018; Paganelli et al., 2017). Recent research has uncovered two common misconceptions about making among preservice and early career teachers: 1) that making consists of hands-on activities designed to achieve specific content learning goals and 2) that making is largely dependent on the use of digital fabrication tools, such as 3D printers (Cohen et al., 2018). A smaller number of studies have focused on making in school libraries (e.g., Fontichiaro, 2018). "Magical Object Syndrome," another misconception that seems to be commonly found among school librarians who are new to making, is the belief that students will learn from the tools themselves and that all a teacher has to do is lay them out (Fontichiaro, 2018). Researchers contend that it takes a knowledgeable teacher to deeply engage students with tools and their functions (Fontichiaro, 2018); and although digital fabrication is often the first type of making activity that teachers will take up with their students (Blikstein, 2013; Smith et al., 2015), it is the making process, community infrastructure, and the maker mindset taken together that, arguably, comprise the Maker Movement's promised contribution to N-12 education (Martin, 2015).

Making in the classroom. Research has uncovered the existence of pioneer teachers who are implementing a version of making in their classrooms, with or without formal professional development (Eriksson et al., 2018; Lindsey & DeCillis, 2017). There is a scarcity of published research to date that has focused specifically on these teachers. Therefore, it is difficult to give an

accurate description, based on empirical research, of how these pioneer N-12 teachers think or practice. In the absence of research focused on individual teachers, whole-school efforts to integrate making have provided some insight into how teachers are taking up making. Peppler et al. (2016), for example, highlighted strategies that elementary schools used to integrate making with the assistance of a visiting teaching artist: One school started with a traveling cart filled with making materials that teachers could sign out and bring to their classrooms; another school used a dedicated STEAM room filled with materials that teachers could reserve for use with their students. It seemed that although the traveling cart provided opportunities for early childhood and elementary teachers to bring making into their own classrooms and get a sense of how it might physically fit into their classroom space, no one took ownership of the cart, and over time it became disorganized and difficult to use. The dedicated STEAM space, located at a different site, was monitored by the principal who made sure it stayed organized. The well-stocked STEAM room created visibility for making in the school; however, its availability seemed to prevent teachers from attempting to integrate making into normal classroom activity. In addition, teachers lost time transitioning back and forth from their classrooms. Peppler et al. (2016) also found that top-down efforts to integrate making were less successful than bottom-up efforts. For example, when one principal directed a grade level to pilot making for the school, the teachers responded with mixed levels of enthusiasm. In contrast, when another principal allowed teachers to opt-in to the pilot program, volunteers were all very committed.

A dissertation case study that tracked the introduction of a FabLab in a high school, found that the addition of the FabLab furthered already existing social divisions between students enrolled in the career technical track and college-bound students who viewed the FabLab as an extension of their AP STEM courses (Lacy, 2016). In contrast, a study of a

makerspace that was introduced in another high school observed that the students who used the makerspace came together from a range of academic tracks and seemed to experience few status distinctions and gendered practices (Puckett et al., 2016).

Suggested approaches to implementing making. Despite the small amount of research that sheds light on how teachers *are* engaging students in making, several researchers and pundits have contributed to a body of literature that suggests how teachers *should be* engaging students in making. First, makerspaces should typically possess elements of the shop class, home economics, art studios, and science labs (Dougherty, 2012; Schad & Jones, 2020). Students ought to work together in mixed-age groups to encourage older or more experienced students to step into the role of "expert" (Halverson & Peppler, 2018). Making projects, ideally, should provide students with more autonomy over the tools and materials they use while they work in a more self-directed manner (Bevan et al., 2014; Martinez & Stager, 2013; NMC & CoSN, 2015). The teacher should deliberately step back into a coaching role where she more often offers suggestions or asks students questions to guide them toward discovery instead of giving specific instructions (Bevan et al., 2014; Campos et al., 2019; Chan & Blikstein, 2018; Clapp et al., 2016; Martinez & Stager, 2013). The teacher should rotate and visit with individuals and groups to help guide them (Campos et al., 2019; Clapp et al., 2016; NMC & CoSN, 2015) and allow time in the curriculum for independent *and* collaborative learning and problem-solving (Bull et al., 2015; Chan & Blikstein, 2018; Martinez & Stager, 2013). The teacher should also recognize that student learning and making processes might look different depending on the focus of the making activity and, for this reason, might require different planning and supervision. For example, facilitating an interest-driven student project compared with facilitating a group of students tinkering with open-ended materials (Clapp et al., 2016; Honey & Kanter, 2013;

Martinez & Stager, 2013). An interest-driven project could be anything a student decides to make, such as a video game, and could require, for example, downloading a special computer application and a great deal of teacher support over the course of days or weeks. Tinkering with open-ended materials, in contrast, might be a one-day activity and require far less planning and teacher support.

What sets making projects apart, ideally, from more conventional small-group or hands-on instruction in the classroom is that the work students engage in while making should be more student-directed and open-ended (Petrich et al., 2013). That is, teachers should frame possible maker activities by focusing student attention on certain concepts, such as electronic circuitry (Bevan et al., 2014; Eisenberg & Buechley, 2008), on certain tools or types of material, such as cardboard and duct tape or 3D modeling software (Bevan et al., 2014; Clapp et al., 2016; Resnick & Rosenbaum, 2013), or a certain problem that needs solving, such as how to get a robot to climb a ramp (Chalmers, 2018; Clapp et al., 2016; Dougherty, 2012; Resnick & Rosenbaum, 2013). But beyond providing the rules and “how-tos" involved in introducing new tools and a few suggestions to help uncertain students get started, in an ideal classroom scenario where students are engaged in making, the teacher should lay out no specific procedures for students to follow or prescribed outcomes (Petrich et al., 2013). Resnick and Rosenbaum (2013) refer to this as a bottom-up approach to learning through making. That is, the teacher should not walk students step-by-step through the iterative design process or have students all “create” the exact same thing by the same due date. Instead, student makers ideally would be allowed to “mess around” with materials until struck with an idea; or they might start with their own tentative goal (e.g., to make a bed for a pet or, to be more inventive, a gadget that will prevent pencils from rolling off student desks) and then play around with the materials available to them

until they eventually achieve their goal (Resnick & Rosenbaum, 2013). A key aim behind making in the classroom is to engage students in processes of learning to design and innovate with the goal of producing something (ideally new) that they can share with others (Halverson & Sheridan, 2014; Kafai et al., 2014; Petrich et al., 2013; Resnick & Rosenbaum, 2013). The making activities that teachers engage students in should demand that students draw on their own knowledge, take risks with their ideas, and operate on the edge of their understanding, like artists, designers, scientists, and engineers (Petrich et al., 2013). Teachers who implement making should ideally design activities that inspire self-confidence and foster the development of design and entrepreneurial skills that students can immediately apply in the real world (Clapp et al., 2016; NMC & CoSN, 2015) sometimes to address local problems or needs (Blikstein, 2008; NMC & CoSN, 2015). In sum, there is no shortage of instructions for teachers who want a recipe for setting up a makerspace and getting started with making in their classrooms.

Problem Statement

My research interest in making extended to all of the various forms of making that the literature claimed is happening in K-8 schools. These included 3D printing, tinkering, and robotics. I was also interested in the influence of the Maker Movement, in general, on teachers; claims made by Maker Movement researchers and pundits regarding benefits to students (e.g., Blikstein, 2008, 2013; Clapp et al., 2016; Dougherty & Conrad, 2016; Halverson & Sheridan, 2014; Honey & Kanter, 2013; Peppler et al., 2016), and claims regarding the ways in which teachers ‘ought to be’ implementing making in schools (e.g., Gerstein, 2014; Martinez & Stager, 2013; Terrell, 2014).

A review of the peer-reviewed academic literature indicated that although there has been an abundance of empirical inquiry into making in recent years, interestingly, and despite growing

interest in the integration of making into N-12 education, little seems to be known empirically about the ways in which pioneer N-12 teachers think or practice in relation to engaging students in making and creating makerspaces in their own classrooms.

To date, the growing body of empirical research on making and education includes a number of studies that focus on making within community makerspaces, such as those housed in museums or public libraries (e.g., Bevan, et al., 2014; Keune & Peppler, 2019; Koh & Abbas, 2015; Lakind et al., 2019; Moorefield-Lang, 2015; Sheridan et al., 2014; Slatter & Howard, 2013; Willett, 2016). A small number of studies have investigated making in school libraries (e.g., Austin, 2017; Bowler, 2014; Craddock, 2015; Fontichiaro, 2018). Several empirical and descriptive studies have examined N-12 students learning in school makerspaces, with some of these studies focused on student interactions with specific tools such as digital toolkits, electronic textiles, storytelling making kits, and tangible game interfaces (e.g., Bekker et al., 2015; Buechley et al., 2013; Christensen & Iversen, 2017; Chu et al., 2017, 2015; Clapp et al., 2016; Kafai et al., 2014; Lee et al., 2014; Litts et al., 2017).

In addition to the studies mentioned above, there have been a few empirical inquiries into how teachers learn to implement maker activities with formal preservice preparation or in-service professional development (e.g., Cohen et al., 2018; Paganelli et al., 2017; Peterson & Scharber, 2018; Schelly et al., 2015). However, a larger share of recent maker education empirical studies examined the use of scaffolds or proxies for teacher expertise in implementing making, such as a mandated national maker education curriculum (e.g., Eriksson et al., 2018), pre-packaged digital toolkits or programmable construction kits (e.g., Chu et al., 2015; Katterfeldt et al., 2015) and guest maker educators working as school makerspace co-facilitators (e.g., Campos et al., 2019; Peppler et al., 2016) suggesting a trend toward schools and

governments employing a top-down approach to integrating making into N-12 education and another possible trend toward researchers producing maker "kits" or services that can then be sold to schools. The bulk of the studies that focused on testing toolkits and curriculum mandates were conducted in Europe.

A California study that investigated guest makers as co-facilitators found that the guest makers were more inclined to promote non-directed exploration of materials with students and ignore off-task behavior while N-12 teachers were more likely to provide students with direction as they worked and respond to student behavior. The researchers also observed tension among teachers and students over differing ideas about what makerspace behaviors counted as work versus play (Campos et al., 2019). Another California-based study that focused on student-student and teacher-student interactions in two middle school makerspaces found that teachers were asking questions, making suggestions, and directing students to available tools or options as needed. It also described how a teacher anticipated and effectively redirected potentially disruptive student behavior in the makerspace setting (Chan & Blikstein, 2018).

In sum, despite growing empirical interest in the integration of maker activities into the N-12 school curriculum, it seems that most of this interest is concentrated on student learning, testing of curriculum products and toolkits, and teacher professional development tied to whole-school efforts to integrate making. Very little direct attention has been paid to 'pioneer' N-12 teachers who are engaging students in making. This gap in the research obscures our understanding of how teachers think about making, how they practice as teachers and makers, and how their school context might influence their teaching and making practices.

The Research Questions Guiding This Study

So far in this chapter, I have provided some insight into why the Maker Movement seems to appeal to many teachers, reviewed how some schools have attempted to integrate making or introduce makerspaces, and presented perspectives from researchers and pundits on how teachers could successfully implement making in schools. Lastly, I described the gap in the empirical research that leaves teachers' actual experiences with implementing making in their classrooms largely undocumented. I designed the present study to help address this gap.

To inform further developments in research on teaching, teacher education, educational leadership, making, and 'maker education' as well as professional development initiatives and school policy, this study asked: *In what ways do three K-8 teachers appear to be conceptualizing and implementing making with students?*

The three research questions guiding data collection for this study were:

1. In what ways do three K-8 teachers appear to be conceptualizing making with students?
2. In what ways are three K-8 teachers implementing making with students?
3. To what extent do claims regarding how "good maker teachers" *should* practice pan out within three actual school-based contexts?

Research Aims

As I mentioned in previous sections, although my main intention for this study was to gain insight into how teachers include Maker Movement practices with their teaching practices, I was also keenly interested in evaluating whether claims that have been made in the literature describing 'ideal' ways to engage students in making (identified earlier in this chapter) bear any resemblance to what teachers are actually doing. My appreciation for the idea of making in

schools is based on what I know about the pedagogy of John Dewey, which is in many ways evident in maker activities (Clapp et al., 2016; Gerstein, 2014; Hogg, 2014; Martinez & Stager, 2013), as well as a recognition of what Smagorinsky (2010) and Tyack and Tobin (1994) described as persistent, conservative norms of teaching in American schools that could very well be interpreted as directly conflicting with the norms of the Maker Movement. Smagorinsky (2010) characterized the central tradition of American educational practice as "authoritarian" in nature. He went on to contrast traditional American teaching with Deweyan progressivism, which, in his view, placed emphasis on the child over the subject, on knowledge as constructed rather than fixed, on the authority of the learner's constructions over that of the text, on discovery instead of rote learning, and on activity in place of passivity. Hogg (2014) made direct connections between maker teaching and Dewey, highlighting Dewey's assertion that the central problem with traditional American schooling is that it had little relation to the real workings of the world and, therefore, inadequately prepared children for adult life. Hogg (2014) argued:

> [C]entral to the maker pedagogy is that learning must be meaningful and have a purpose for the child. It is about creating meaningful products—not just doing for the sake of doing. Children must be involved in tasks that include real life problem solving that is relevant and meaningful to them and their world (para. 4).

I was interested in observing how the meeting of these two seemingly contrasting practices—teaching and making—plays out in the school setting as it is negotiated by teachers. I believe my findings could prove meaningful to researchers, teachers, teacher educators, school leaders, and policy makers interested in investigating, implementing, supporting, or facilitating maker teaching.

Chapter 2: Literature Review and Theoretical Framework

As I mentioned in Chapter 1, the purpose of this study was to examine how three K-8 teachers were thinking about and implementing Maker Movement practices as they engaged students in making in the formal classroom setting. I was also interested in how the teachers navigated the norms of the Maker Movement, their school contexts, and the field of N-12 education. By focusing my attention on teachers who were engaging students in making, I uncovered a gap in the peer-reviewed literature on making in N-12 schools. In this chapter, I situate my study in the extant literature and describe the theoretical framework I used to orient the study and inform my data collection and analysis. Before that, however, I provide a brief historical and descriptive overview of the Maker Movement to help illuminate the varied and complex societal forces that could motivate teachers to engage students in making. I include this overview because it is uncertain whether teachers who engage students in making were inspired by what they know about the Maker Movement, what they know about what the literature refers to as "maker education," or whether they were simply inspired by the same factors that created the Maker Movement. I also discuss varied conceptions of *maker* and *making*, an identity/activity that has not yet been clearly defined by consensus and perhaps is still evolving.

History of Makers and the Maker Movement

Makers have been commonly defined as creators with a love for exploration and play; they are imaginative builders and shapers who enjoy the learning process involved in producing new tools and exploring new kinds of manufacturing (Clapp et al., 2016; Dougherty & Conrad, 2016; Honey & Kanter, 2013). They also have a *maker mindset*—that is, they see themselves as "empowered" to solve problems and make changes to their work, their lives, and within their communities (Dougherty, 2012; Dougherty & Conrad, 2016; Gerstein, 2014; Natanagara, 2017).

The launch of Dale Dougherty's magazine *Make:* in 2005 named and helped define the Maker Movement as a phenomenon (McCracken, 2015). Dougherty, known for his keen ability to identify trends, targeted the *do-it-yourself* (DIY) technology hobbyists who liked to take apart, tinker, and create new things with electronic tools they had on hand—the type who might design a Raspberry Pi-powered spy camera and attach it to her cat (McCracken, 2015). However, the early association of making with electronics hobbyists eventually broadened to include crafters and other types of hobbyists (Davies, 2017; Hatch, 2013). The overwhelming popularity of *Make:* inspired the first Maker Faire in 2006. Other Maker Faires followed and over time the word "maker" became a badge of pride; a new identity for makers of all types, such as artists, crafters, electronics hobbyists, engineers, and mechanics of all ages (Dougherty & Conrad, 2016).

Social and Economic Context of the Maker Movement

The Maker Movement is far from the first DIY movement America has seen. During the nineteenth century, for example, before the U.S. had a central bank and the economy was less stable, the concept of productive leisure gained traction (Amadeo & Rasure, 2022; Science Museum, 2020). An artifact from this era is a book called *Practical Education* (Edgeworth & Edgeworth, 1815):

> The more natural vivacity and ingenuity young people possess, the less are they likely to be amused with the toys which are usually put into their hands. They require to have things which exercise their senses or their imagination, their imitative, and inventive powers (p.10).

Large families were common, and valued, in the 19th century (Livni & Kopf, 2017). Economic turbulence just before and after the turn of the 20th century seemed to tie in with parents and

children making most toys at home (Follender, 1987; Onion, 2018). There was a need for thrift, and there was also the belief that children would find amusement and satisfaction in making their own toys.

In 1872, the magazine *Popular Science Monthly* started circulating. Much like *Make:* magazine, it was targeted to the educated science and tech enthusiast (Hatch, 2013; Ockerbloom, n.d.). The magazine enjoyed wide appeal among a generation of DIYers inspired by the unprecedented advances in technology that had taken place within their lifetime (Martinez & Stager, 2013; Schmoop University, 2017). Later, during the Great Depression, many Americans resorted to DIY projects to 'keep up appearances' and mask financial hardship (Science Museum, 2020). During WWII, when consumption of materials and goods were highly regulated and rationed, DIY efforts such as women making and patching clothing at home were celebrated as patriotic (Matchett, 2019). The 1970s, another period of economic recession, set the Punk Movement in motion. Originally driven by Marxist ideologies concerned with young British musicians' desire for control over their own music production, as it made its way to the U.S. it was more generally associated with anti-establishment attitudes and freedom of self-expression (Saba, 1980). Closer to the end of the 20th century, the Maker Movement developed when new technologies became available for home use and the Internet made it relatively easy to connect with other hobbyists to exchange ideas (Fallows, 2016). A recession in 2008 corresponded with the release of desktop 3D printers (Berman, 2012). This was a meaningful development for entrepreneurs and small startups because it created access to cheaper means of production (Fallows, 2016). Previously, 3D printers cost tens of thousands of dollars and were only designed for commercial use. With small, inexpensive 3D printers, anyone could design, prototype, and manufacture goods from home.

What seemed to distinguish the Maker Movement from earlier DIY movements is its identity as a socially-connected community, facilitated by the Internet. Another distinguishing feature is its creation of devoted physical spaces known as makerspaces. Like other DIY movements, the maker community is associated with self-reliance (Clapp et al., 2016; Davies, 2017; Dougherty & Conrad, 2016), but some have also associated the Maker Movement with an ethic of social justice (Blikstein, 2008; Davies, 2017; Dougherty & Conrad, 2016).

A contentious Maker Movement practice known as *open-sourcing* has, in fact, been applied in socially conscious ways. Open-sourcing challenges conceptions of intellectual property by inviting others to freely take and improve upon one's digital work. This practice decentralizes and accelerates innovation, and it serves as an alternative to proprietary traditions such as copyrights and patents. "True open source communities are 'open-by-rule'—they have a governance that ensures no single community member can exploit the others" (Phipps, 2016, para. 3). An example of an open-sourcing effort that evolved into community service is the RepRap Project (Jones et al., 2011). In 2005, an English mathematician and engineer, Adrian Bowyer, designed a self-replicating 3D printer and made the file available as a free download for others to improve. Bowyer is now widely credited with starting the low-cost 3D printing revolution (RepRapWiki, 2018). The availability of a self-replicating 3D printer made it possible for startup manufacturers to acquire multiple 3D printers at minimal cost, greatly reducing their overhead. A British newspaper article jokingly referred to the RepRap Project as an attempted takedown of global capitalism (Randerson, 2006). However, others have insisted that accessibility to technologies such as 3D printers could democratize the tools of production (Britton, 2014).

Reasons for Making

As I mentioned earlier, the Maker Movement was originally associated mainly with tech enthusiasts (Buechley, 2014; Clapp et al., 2016; Dougherty & Conrad, 2016; Honey & Kanter, 2013; NMC & CoSN, 2015). Further investigation, however, uncovered a much broader array of making activity. Hatch (2013) included crafters in his description of makers. Davies (2017) included crafters, home bakers, canners, and other kinds of artisans. A review of the Maker Movement literature indicated that this broader array of makers identified with a more varied set of purposes than self-reliance and social justice. Table 1 below provides an outline of maker purposes that have emerged in the Maker Movement literature.

Table 1

Strands of Purposes within the Maker Movement

Purpose	Proponents	Rationale/Background
Making creative design more universal and democratic	Barnatt (2016) Eisenberg and Buechley (2008)	The Maker Movement invites everyone to participate in their society as producers, not just as consumers.
Community-based creativity, innovation, and entrepreneurship	Davies (2017) Dougherty and Conrad (2016)	Publicly accessible fabrication facilities (aka hackerspaces; makerspaces; fablabs; techshops) provide individual inventors and entrepreneurs with access to the means of production, or fabrication tools, as well as a community that supports their creative purposes.
STEM-based career pipeline	Bull et al. (2015) Obama (2009)	With the introduction of advanced manufacturing technologies into the school curriculum, students of all ability levels and

		backgrounds can participate with the goal of increased diversity in the STEM pipeline.
Economic development	Barnatt (2016) Blikstein (2013)	3D printing can stimulate the economy through customization, for example, which can make products more efficient and better adapted to their application; through new kinds of manufacturing jobs; and through distribution of manufacturing to local service bureaus which can reduce transportation costs (Barnatt, 2016).
Crowd economy	Jones et al. (2011) Houlihan and Harvey (2018) Nekal (2014) Rifkin (2011)	"[This] dynamic ecosystem of productive people … participate through a platform with a purpose to achieve mutually beneficial goals" (Nekal, 2014, para. 3). The crowd economy represents a change in perspective: A new economy based on a sense of abundance replaces an old economy built on scarcity and fear (Houlihan & Harvey, 2018).
Inquiry-based educative practice	Bevan et al. (2014) Bull et al. (2009) Clapp et al. (2016) Martinez and Stager (2013) Resnick and Rosenbaum (2013) Vossoughi and Bevan (2014)	Engineering is about designing solutions to recognized problems and needs, therefore Maker Movement-inspired learning should be grounded in problems that are practical and real and should deal with the larger contexts in which these challenges emerge.

Social action	Blikstein (2013) Davies (2017) Hatch (2013)	Projects can be deeply connected with meaningful problems, either at a personal or community level, and designing solutions to those problems can become both educational and empowering.

While a common purpose for making seems to be rejection of consumer culture, making within particular domains may have more specific purposes. For example, a rationale behind food-related making is cynicism and distrust in commercial food production, marketing, and transportation (Davies, 2017). Many home gardeners, chicken farmers, and makers of foods such as yogurt, jams, honey, breads, and cheese want more control over the quality of food they consume or hope to save money. Alternatively, some wish to engage directly in creating good things to eat. Others have concerns for the environment.

Emerging Definitions of Maker and Making

In addition to describing the multiple purposes of making (above), I also describe emerging definitions in the literature of "maker" and "making." Tables 2 and 3 below are summaries I have generated for understanding emerging definitions of "maker" and "making" as described in the Maker Movement literature, beginning in 2013. The tables illustrate how some of the earlier definitions of "maker" and "making" emphasized the role of computational thinking and digital tools; however, more recent definitions seem to place less emphasis on electronics and include a more diverse range of processes, tools, and materials.

Table 2

How "Maker" is Defined

Definition of "maker"	Author(s)
"[Maker is] a way to describe someone who engages in the act of making, perhaps even a profession, like *artist* or *sculptor* or *crafter*. A maker might be someone who bakes bread or someone who quenches steel… ultimately a maker is…anyone… who makes things" (p. 5).	Clapp et al. (2016)
Makers, also known as hackers, engage in making activities as a form of 'serious leisure'—a deeply meaningful pursuit that involves perseverance, challenges and frustrations, and the gradual accumulation of skills and abilities. It allows one to become part of a larger project and to develop and enrich one's sense of self (Chapter 2, para. 15).	Davies (2017)
"Makers are producers and creators, builders and shapers of the world around us. Makers are people who regard technology as an invitation to explore and experiment, with the most inclusive possible definition of technology, meaning any skill or technique that we learn and employ. What we once called hobbyists, tinkerers, artists, inventors, engineers, crafters—all of them are makers. The power of "maker" as a new term lies in its broad application, its sense of inclusiveness, and its lack of close alignment with a particular field or interest area, so people are free to claim the identity for themselves" (Introduction, para. 2).	Dougherty and Conrad (2016)
"Being a maker … involves participating in a space with diverse tools, materials, and processes; finding problems and projects to work on; iterating through designs; becoming a member of a community; taking on leadership and teaching roles as needed; and sharing creations and skills with a wider world" (p. 529)	Sheridan et al. (2014)
"No one would argue that computers have changed every aspect of life over the past few decades. As computers become smaller, and more powerful, and cheaper at the same time, they become embedded into objects and tools, changing the way that people interact with tools. For the first time, 'smart' tools allow people to design their own objects and quickly fabricate them in the real world. Online communities serve as the hub of a digital learning commons,	Martinez and Stager (2013)

allowing people to share not just ideas, but the actual programs and designs that they have made. This ease of sharing lowers the barriers to entry as newcomers can easily use someone else's code and design as building blocks for their own creations. Amazing new tools, materials, and skills turn us all into makers" (Introduction, paras. 5-7)	
"Makers are drawn together by a shared delight in the magic of tinkering, hacking, creating, and reusing materials and technology. The essential characteristics of the maker sensibility—deep engagement with content, experimentation, exploration, problem-solving, collaboration, and learning to learn—are the very ingredients that make for inspired and passionate STEM learners" (p. 3).	Honey and Kanter (2013)

In fact, in Table 2, more recent definitions omit any reference to tools or materials and focus instead on the person and personal processes such as learning and self-development.

Table 3

How "Making" is Defined

Definition of "making"	Author(s)
"Specifically, three constellations of characteristics [stand] out as exemplifying typical [making] components: characteristics related to community, characteristics related to process, and characteristics related to environment…Within the constellation of community characteristics… collaboration, distributed teaching and learning, the combination of diverse skills and expertise, and an expectation to share information and ideas…Within the constellation of process characteristics, curiosity-driven, experimental learning along with rapid prototyping, an interdisciplinary approach to problem solving, and flexibility…And within the constellation of environmental characteristics, open spaces, accessible spaces, and tool- and media-rich spaces…" (p. 7).	Clapp et al. (2016)
"[M]aking is something humans are wired to do. It comes naturally to us, using our hands and minds, to create, explore, and communicate. It is something we can do once we have an idea about what we want to do. Making is a kind	Dougherty and Conrad (2016)

of "what if," exploring questions as to how something works and if it could work differently" (Introduction, para. 6).	
"[Making] is about moving from consumption to creation and turning knowledge into action. In pedagogical terms, it is firmly located within the broadly constructivist philosophies of education" (p. 6).	Fleming (2015)
"Making is fundamental to what it means to be human. We must make, create, and express ourselves to feel whole. There is something unique about making physical things. These things are like little pieces of us and seem to embody portions of our souls" (p. 2).	Hatch (2013)
"Digital fabrication and "making" are based on three theoretical and pedagogical pillars: experiential education, constructionism, and critical pedagogy" (p. 4).	Blikstein (2013)
"Making involves constructing, building, and using hands, but all the work is permeated with two socially valued practices: computation and mathematics. The familiar practices of building and making are augmented with computational tools, which generate not only more refined and sophisticated projects, but also empowerment and increased self-esteem" (p. 7).	Blikstein (2013)
"Make—to build or adapt objects by hand, for the simple personal pleasure of figuring out how things work" (p. 3).	Honey and Kanter (2013)
"[Making, or u]sing technology to make, repair, or customize the things we need brings engineering, design, and computer science to the masses" (Introduction, para. 7).	Martinez and Stager (2013)

Interestingly, definitions of making in Table 3 seem to align more closely with some of the purposes outlined in Table 1 more than others. In fact, all definitions in Table 3 associate making with learning or using knowledge to create something not just for the sake of production but for the intrinsic benefits of the making process that contribute to self-esteem and enjoyment.

Situating the Study

As I have stated previously, there is little extant research that has focused specifically on 'pioneer' teachers who engage students in making, therefore this study helps to fill a gap in the literature on making in N-12 schools. The purpose of this study was to examine how three K-8 teachers think about and implement Maker Movement practices as they engage in making with students in the formal classroom setting. As part of this investigation, I was interested in how teachers navigated the norms of the Maker Movement, their school context, and the general N-12 education context. A review of the growing body of empirical inquiry into the more general effort to integrate making into N-12 education indicated that most of this interest is concentrated on student learning, testing of curriculum mandates, products, and toolkits, teacher professional development, and school reform efforts. Very little direct attention has been paid to 'pioneer' N-12 teachers who are implementing making in their classrooms without imposed professional development, curriculum kits, or whole-school collaborations with outside partner organizations that provide visiting makers to co-facilitate or co-teach. This gap in the peer-reviewed research makes it difficult to understand how teachers implement making in classrooms, what they think, and how the overlapping and nested contexts of their school, the Maker Movement, and the field of N-12 education might influence their teaching and making practices.

With so few published studies available that have reported findings related to teachers' insights or teachers' practices as they engage students in making, I situated my study to follow two studies that, among their findings, made mention of teachers in practice. The first is a California study that investigated teachers and guest makers as co-facilitators in school makerspaces: Campos et al. (2019), which was presented in a conference paper, focused on the interactions of credentialed and non-credentialed teachers working together in a recently adopted

maker program that was being implemented in California schools. The researchers conceptualized maker education as a boundary pedagogy "where the borders of formal and informal education are blurred" and therefore used observations and interviews to study behavioral and organizational aspects of the program. "Considering that discourses can shape practices," the researchers examined vocabulary the pairs of educators used, "revealing tacit and manifest conflicts in the studied schools" (p.1). The first round of data analysis applied *a priori* codes drawn from the literature and central to the researchers' work. The second round analyzed educators' vocabulary. These new vocabulary-based codes were added to the initial *a priori* codes and grouped into concepts. One observation discussed in the findings was that guest makers were more inclined to promote non-directed exploration of materials with students and ignore student behavior while N-12 teachers were more likely to provide students with direction and respond to student behavior. Another tension, observed between teachers and students, related to differing ideas about what makerspace behaviors counted as work versus play. Another California-based study, part of a larger study and conducted as an independent honors thesis project, investigated design and engineering classes in two middle school digital fabrication makerspaces that use a problem-based learning (PBL) approach (Chan & Blikstein, 2018). Each FabLab makerspace was run by one or two designated teachers with titles such as "FabLab Director," "Makerspace Coordinator," or "Science Teacher." The researchers used observations of students and semi-structured interviews with the teachers to uncover the nature of student-student and teacher-student interactions. Data analysis consisted of one investigator reviewing data for recurring themes and organizing them into categories. The study revealed that teachers were asking questions, making suggestions, and directing students to available tools or options as

needed. The researchers also noted how one teacher anticipated and effectively redirected potentially disruptive student behavior in the makerspace setting (Chan & Blikstein, 2018).

Taking the findings of the studies described above into consideration and aiming to contribute to the existing research on teachers who include making and the possible frictions that could stem from attempts to implement classroom-based making, this study asked: *In what ways do three K-8 teachers appear to be conceptualizing and implementing making with students?* My goal was to shed light on the interplay between Maker Movement practices, N-12 teacher practices, and school context.

Theoretical Framework

In this section, I describe the theories and related concepts that I used to understand my research data. I was interested in understanding how the three teachers navigated tensions and made decisions related to conflicting values, interests, and pressures that resulted from having to work within the overlapping and nested contexts of their school, N-12 education, and the Maker Movement. To gain insight into teacher decision-making, I turned to my data using Discourse theory (Gee, 2014), self-authoring theory (Bakhtin & Holquist, 1981; Holland et al., 2001), history-in-person theory (Holland et al., 2001; Holland & Lave, 2001), and grammar of schooling theory (Tyack & Tobin, 1994) which I describe in the following paragraphs.

Gee (2014) developed Discourse theory to explain how communities of practice form. He argued that a *Discourse*, by its nature, has a norming effect that supports necessary socio-linguistic and sociological purposes, such as socially-networked "storage" of group knowledge and the apprenticeship of new members. Moreover, if members of a Discourse determine that one's practice deviates too far from that of others, "the Discourse will 'discipline' you and pull you back in line or you will cease to be [a member of that Discourse]" (Gee, 2014, Location No.

2188). I applied this lens as a way to understand how the three teachers understood their maker practices in relation to their N-12 teaching practices and how engaging students in making might have influenced their relationships with other teachers in the school. Bakhtin (Bakhtin & Holquist, 1981), influenced by the social turmoil of post-revolutionary Russia, was more interested in the individual's relationship to Discourses. Using the term *authority* instead of Discourse, Bakhtin also acknowledged the conforming aims and purposes of authorities, but he foregrounded the natural human compulsion to respond to messages from authorities—and any other messages from the social world— with a point of view. He likened this compulsion to the body's involuntary responses to environmental stimuli. Bakhtin (Bakhtin & Holquist, 1981) argued that by answering the social world, one *authors* it and oneself; that within the dynamic and dialogical relationship between person and authority, both continue to develop (Holquist, 1983). Self-authoring theory helped me understand how the three teachers' identities as makers influenced their decision-making in the classroom and their school context. Building upon Bakhtin's (Bakhtin & Holquist, 1981) self-authoring theory, Holland and Lave (2001) foregrounded the relation between engagement in contentious local practice and identity development. *Contentious practices* are those that lack legitimacy and consequently present a threat to the reputations of individuals and organizations (Gonsalves, 2020). Holland and Lave (2001) argued that taking part in contentious local practice shapes one's identity in complex ways and forms a ground for agency that guides one's behavior. Moreover, the working out of local ways through contentious practice is always part of a larger historical, cultural, political, or economic struggle that—perhaps indirectly or invisibly—influences identity development as well. I used history-in-person theory to understand how the three teachers responded to the

nested and potentially conflicting pressures of the school context, N-12 education, and the Maker Movement.

Tyack and Tobin's (1994) *grammar of schooling theory* helps make sense of similarities in teaching practice across schools by suggesting that there are institutionalized structures and practices that cut across all N-12 schools. The grammar of schooling contends that society persistently associates the concept of school with the characteristics of the earliest schools that were established more than a century ago. These include physical characteristics, such as classrooms with desks and designated presentation areas, hallways, lockers, a main office, and fields or playgrounds outside; and organizational characteristics, such as content areas, grade levels, class schedules, report cards, and a hierarchical decision-making body. Also subject to scrutiny under this grammar of schooling lens are the activities that take place within a school, such as instructional delivery, student evaluation, and student discipline. Similar to Gee's (2014) Discourse theory, Tyack and Tobin's (1994) grammar of schooling theory contends that the further a school departs from this socially constructed conceptualization of the school, the more likely it will be rejected as a school. For this reason, numerous efforts to reform or modernize schooling in the past century have failed.

By applying these theories, I was hoping to shed light on how the three teachers in this case study developed identities as makers as they navigated the constraints imposed on their making practice by the conforming nature of teaching, the field of N-12 education, and the school context.

Chapter 3: Research Design

The purpose of this study was to examine how three K-8 teachers think about and implement Maker Movement practices as they engage in making with students in the formal classroom setting. As part of this investigation, I was interested in how teachers negotiated the norms of the Maker Movement in relation to the norms of their school context and the norms of the general N-12 education context. The loosely-defined Maker Movement can be experienced by teachers in different ways, depending on how they learned about it and what they decided to take from it. For example, as I described in Chapter 1, it was my own personal interest in 3D printing from the perspective of a female artist with no formal 3D design or building skills that drew my attention to making. It was only after I observed the iterative process of 3D design that I could recognize its appeal as an elementary educator. My original interest in 3D printing as a useful technology for me and people like me then broadened to a more general interest in making and its possibilities for N-12 education. Nevertheless, some core Maker Movement practices and values have emerged in the Maker Movement literature (Barnatt, 2016; Davies, 2017; Dougherty & Conrad, 2016; Hatch, 2013). Taken together, and to recap, they support individual empowerment through creating, sharing, and open collaboration.

My investigation focused on three teachers, two working in suburban public schools and one in an independent suburban school in northern New Jersey. All taught elementary level students within the range of kindergarten through grade eight. I used a multiple case study methodology (i.e., Yin, 2017) that included multiple visits to each teacher's classroom for observations and in-depth interviews. Because I aimed to study individual teachers from different schools and take into account how the school context and the broader N-12 education and Maker Movement contexts might influence their decisions as teachers and makers, a case

study approach seemed most appropriate. I describe my methods in more detail in the research design section below.

Research Design

Yin (2017) argued that a case study is the preferred research method when investigating a contemporary event or set of events within a context where events or behaviors cannot be manipulated or controlled. Flyvbjerg (2006) argued that in-depth case study research is the only way to understand a complex issue. A "case" in this research sense is the focus of the study. Cases in qualitative research are bounded; that is, limited in scope (Merriam & Tisdell, 2016; Miles & Huberman, 2013; Yin, 2017). The lines between a case and its context might not always be clear; therefore, "the researcher needs to set out the bounds for the case, and to justify how the case can be considered as one instance among others—a coherent and integrated system in its own right" (Taber, 2016). In this study, I defined each case as an individual teacher who is integrating making into his or her school-based practice and his or her school context, which includes all the social and professional relationships within the school environment, and other environmental factors such as school policies, routines, and cultural norms (Miles & Huberman, 2013; Yin, 2017). In addition, I considered each case as nested within the broader contexts of the N-12 education field and the Maker Movement.

Utilizing a multiple-case study design enabled me to investigate each teacher in depth and then compare and contrast the three cases and look for patterns that might usefully illuminate how teachers think about and implement making with students. Flick (2014) advised that keeping some factors constant across all contexts in a multiple case study design helps to focus the study and provides a stronger basis for comparison across the cases. The more factors held constant across cases, the more likely certain outcomes will be similar (Baxter & Jack, 2008). For this

reason, my investigation focused on three teachers in suburban Northern New Jersey schools who teach the full range or within the range of grades between kindergarten and eighth grade. I was interested in teachers working within this grade level range because I had learned, anecdotally, of elementary and middle schools that had integrated making so that it was accessible to most or all students. For example, teachers had created makerspaces in classrooms, technology labs, STEM labs, art rooms, or school libraries.

Case Description

For the purposes of this study, a case is defined as a 'pioneer' teacher of students in the range of grade levels kindergarten through eight who is engaging students in making in his or her classroom. A pioneer teacher is one who has initiated making with students on a voluntary basis in the absence of whole-school or district goals to integrate making.

Contexts and Selecting Schools

Context, in the sense in which I am using it here, supplies the lenses through which all parts of this study (methods, arguments, findings, conclusions, and recommendations) can be viewed. This includes its methods, arguments, findings, conclusions, and recommendations. The context can be geographical, historical, cultural, or topical and provides the picture of the 'where', 'who', 'what', and possibly the 'when' of the research (Rahman, 2017; Yin, 2017). Each of my cases, a pioneer K-8 teacher who is engaging students in making, is bounded by the immediate context of his or her school. The school context includes students, colleagues, school leaders, parents, the physical teaching and work environment, school climate and culture, the existing and aspirational curriculum, school goals and strategic plans, the school mission, policies, routines, and current points of pride, challenges, or issues that might be under discussion within the school community.

In addition, all three cases are nested within the larger contexts of N-12 education at the state and national level and the Maker Movement. The N-12 education context, in general, includes the knowledge, practices, and ethics of N-12 practitioners, including teachers, administrators, counselors, to name just a few; it also includes local board policy, state and national policy. In addition, the N-12 education context includes commercial sectors that influence, support, or profit on N-12 education such as textbook publishing companies, testing services, ed-tech companies, technology companies, and school supply vendors. Further, it includes partner organizations that provide value-added services to schools such as professional development for teachers.

In New Jersey, the N-12 education context includes, for example, the engineering sector which has been advocating for STEM education programs to be created in schools as a strategy to make New Jersey more commercially competitive with Silicon Valley (Research and Development Council of New Jersey, n.d.). At the national level, the N-12 education context includes the standards-based education reform movement (National Research Council, 1996a) which has used legislation such as Every Student Succeeds Act (ESSA) (U.S. Department of Education, n.d.) and the Race to the Top Act (RTTT) (U.S. Department of Education, 2016) to develop top-down school improvement initiatives that influence N-12 practices at the school and classroom level. These initiatives include national content standards, high stakes standardized tests, and teacher evaluation systems.

As I described in Chapters 1 and 2, given the growing attention paid to making in schools as well as a seemingly persistent lack of research that focuses on the teachers' perspective, I was interested in studying teachers who were engaging students in making. Engaging in making could include 3D printing, tinkering, robotics, design thinking, or any of the other permutations

of activity associated with making (see Chapter 2 for more on this). My goal was to observe the teachers' practice and talk to them about what they think about engaging students in making, what it is like to engage students in making, their thoughts about creating a makerspace in a classroom, and how they design a classroom curriculum around making. I was also interested in specific ways in which teachers might be making adjustments to the classroom environment and their instructional practices, such as shifting the classroom layout and organization to (better) support making, increasing the amount of hands-on learning experiences as well as student opportunities for learning through trial-and-error and learning on the spot (cf., Brown & Adler, 2008), adding tools and materials, and spending an increased amount of time in a facilitative role while teaching; to name just a few.

In addition, I also intended to look for ways that the influences of the broader N-12 education context and the Maker Movement might have influenced teachers' decisions in relation to their practice. When selecting participants, I considered both public and independent school teachers for this multiple case study. Public school was a compelling context since I expected there to be some informative and interesting tensions with respect to teachers attempting to balance engaging students in making with the imposition of state-mandated content area standards in STEM and language arts as well as teacher accountability measures, such as standardized testing and teacher evaluation practices, related to current state and federal school improvement policies. I thought these tensions could serve as useful grounds for examining Maker Movement claims regarding the value of bottom up learning (see discussions in Cochran-Smith et al., 2015; Mehta, 2013b; Resnick & Rosenbaum, 2013) and the extent to which the teachers were able to use this bottom up approach in practice. Including an independent school provided another compelling context, especially to use in comparison with the public schools,

because it could possibly provide some insight into what happens in the absence of such state and federal accountability-related tensions and with the added supports and resources sometimes found in these privately-funded learning environments.

Participants

This study investigated how three experienced elementary teachers thought about and implemented making with their students. My criteria for "experienced" was a teacher who had spent enough time in the classroom and the current school to feel confident using his or her own discretion when making instructional or curricular decisions, for example, decisions about which Maker Movement practices he or she might adopt and which he or she might reject or modify. I was not interested in teachers with a tendency to accept new curricula or instructional strategies without question or without making thoughtful modifications because such teachers, most likely, would be less reflective about their teaching.

I used purposive sampling (Yin, 2017) to select three participants by contacting teachers whom I knew to be integrating maker education and also broadcasting among the teachers and school administrators in my social network that I was interested in studying teachers who were engaging students in making. Purposive sampling is the purposeful selection of individuals to participate in a study for specific reasons that stem from the core aims and constructs of the research questions (Flick, 2014; Merriam & Tisdell, 2016; Ravitch & Carl, 2016; Yin, 2017). Several of my personal connections offered up their schools as study sites and/or recommended teachers for selection, so I was presented with a wide field of potential participants.

One participant I selected for this study, "Mary," taught technology as a special to students in grades three through eight and as enrichment to grades one and two in a small public PreK-8 district where students progressed from Pre-Kindergarten to grade eight in one school

building. My second participant, “Sandra,” taught STEM as an elective to grades six through eight in a public middle school that was part of a PreK-12 district. My third participant, “Eli,” taught fourth grade social studies at the K-5 Lower School site of a K-12 independent school. Table 4 provides a summary of participants and their school contexts. Chapter 4 provides a fuller description of each case.

Table 4

Participant Summary

Case One	Case Two	Case Three
Mary Technology Teacher Grades 1-8 PreK-8 Public School District	Sandra STEM Teacher Grades 6-8 PreK-12 Public School District	Eli Fourth Grade Social Studies K-12 Independent School

Data Collection

A case study relies on multiple sources of evidence for a rich body of data and so that data can be triangulated (Miles & Huberman, 2013; Yin, 2017). I collected a range of evidence in relation to each case: Multiple participant-observation sessions documented with handwritten field notes and audio recordings; interviews with participants documented by audio recordings and handwritten notes; post-lesson debriefing meetings with participants documented by audio recordings and notes; digital images and/or videos of classroom activity, classroom layout, storage areas, wall hangings, bulletin boards, whiteboards with agendas or notes written on them, classroom equipment and materials, teacher plan book pages, academic schedules, participants’ curriculum documents, and student work; school or district-level curriculum documents;

demographic and other salient information about the school or district that are publicly available on the school website; and any written communication between the participants and me, such as emails and text messages. Each of these sources of data is discussed in more detail below. That said, in keeping with recommended case study methods (Merriam & Tisdell, 2016; Ravitch & Carl, 2016; Yin, 2017), observations and interviews served as my main sources of data. Data collection took place over the course of nine months between September 2018 and June 2019, or one school year. Table 5 provides an outline of data sources and the approximate amount of time invested in each.

Table 5

Data Collection Summary for Each Teacher

Interviews	Researcher observations & field notes	Post-lesson interviews	School documents
1 x 60 min. At the beginning of the data collection period 1 x 60 min At the end of the data collection period	8 x 1 day of multiple Makerspace lessons 1 x 30 min. Informal building tour	4 x 30 min. [Teacher reflects on lesson and what took place]	Copies of lesson plans; publicly available curriculum documents; email and text communications with participant

Observations and field notes. As I mentioned above, participant observations served as a main source of data for this study. I observed each participant eight times for five hours each time, which allowed me to see multiple lessons per day and the general flow of the school day. In total, I spent 40 hours with each participant. I spaced my visits out so that I could observe the beginning, middle, and end of a unit of study taught by each participant and the beginning,

middle and end of a semester in each school. I visited the two public school teachers in the fall and winter and the independent school teacher the following spring. My original plan was to conduct direct observations, which would have kept me off to the side and out of the way of the teachers and students at work. My intention was to be nearly invisible so my presence would have little impact on classroom activities. However, the students were curious. Some were even a bit apprehensive about my presence, especially when they realized I was using an audio recorder, so it made more sense to be out in the open and engage with them so I could put them at ease and be less of a distraction. I asked each of the participants to introduce me as a university student who was working on a research project, and that seemed to break the ice with the students. Henceforth, I played a more active role in lessons by rotating around the room and asking students about their work. I knew that conducting observations would allow me to experience firsthand how the teachers performed in the classroom; for example, how they approached maker education, how they planned, whether they followed their lesson plans (if they used lesson plans); what their teaching style was like; how they interacted with students; what personal knowledge, philosophies, and areas of expertise they contributed to the classroom makerspace; and how they managed the makerspace context (Merriam & Tisdell, 2016; Ravitch & Carl, 2016; Yin, 2017). Conducting participant observations added to my experience by allowing me to play the role of an extra teacher in the room and do what my participants were doing. When participants engaged with colleagues, I took notes on what those interactions were like and what the nature of the relationships seemed to be like. I was interested in how the teachers and their colleagues positioned themselves in relation to each other and thought it could give some indication of how influential the participants were among their peers and possibly provide clues as to whether making might spread to other classrooms or curriculum areas in the school.

Because the classroom makerspace is the teacher's main tool, I took digital images of the physical teaching environment, capturing the classroom size and layout, what equipment and materials were provided for learning and how they were used, and where the makerspace classroom was located in the school building. I believed all of these details could provide insights into the status of making in relation to other courses and subjects offered in the school. I also believed it could provide insight into how well each participant and his or her school leaders understood making. I used participant observation data to help triangulate the data I collected through interviews with participants, which I describe in the next section.

Semi-structured interviews. I conducted two hour-long semi-structured interviews (Flick, 2014; Merriam & Tisdell, 2016), with each participant. I planned to complete one interview at the beginning of data collection and one at the end. However, it was necessary to divide up the interview questions for each participant and ask them over the course of a few days. This is because none of the participants had an hour-long break during the school day and on most days could only find 20-30 minutes at a time to sit for an interview. The interviews also ran longer than an hour in total because the participants gave thoughtful, detailed responses to each question. Extending interview sessions for several days left a smaller window of time between the two interviews, but I found no evidence in the data that a lack of distance between interviews had undermined my research goals in any way. As I had hoped, the interview data served as an abundant source of evidence regarding the teachers' own reflections on practicing maker education and envisioning how they might implement it "ideally," if the participants could make certain kinds of changes that they identified. I chose to use semi-structured interviews so that I would have some flexibility to change the order of questions on the pre-written interview

protocol, omit questions, or add questions as needed based on the participant's responses (Flick, 2014; Merriam & Tisdell, 2016). See Interview Protocol in Appendix A.

Post-lesson debriefing meetings. When possible, I met with participants informally in between lessons to discuss the previous lesson. Often, we focused on something unusual that had occurred or something that the teacher found frustrating. Sometimes I needed clarification on something I had heard or observed about the lesson or a student. These brief discussions provided insight into what the participants were thinking about as they were teaching, how they were evaluating themselves, the lesson, the curriculum, and students, and how they were attempting to solve problems.

Document data. Yin (2017) argued that the case study method provides an opportunity to examine varied sources of data to develop a detailed understanding of a phenomenon. With this in mind, I collected various documents and artifacts from each participant and school. These documents included school curriculum documents that were publicly available as handouts in the school office or as posts on the school or district website; emails and text messages between my participants and me; images of my participants' plan book pages, academic schedule, school calendar; announcements and memos posted on bulletin boards, copies of the school or district's vision and mission; Board of Education meeting minutes; and images of student work.

School building tour. When I conducted a pilot study in preparation for this proposed study, I found that most of my participants thought it was important to provide a tour of the building. The tours often included introductions to key colleagues who served as the participants' supporters or collaborators. In this way, I was able to obtain a sense of the school context in general and, in particular, where making was happening in the building and where it was not. The tours, I believed, reflected the participants' pride in their schools, and I found the

tours useful in creating a rough mental map of each participant's social network within the school and in making inferences about how the integration of making might spread to other teachers and classes. For this reason, I asked each participant in this study to take me on a tour of their school building. The Assistant Lower School Director at the independent school stepped in and gave me the tour of the Lower School building. She made a separate appointment with me prior to my first scheduled visit with my participant. The Assistant Director conducted the tour as if it were an admissions tour, which I am familiar with having worked in independent schools. It was very thorough and highlighted the school's strengths. We stopped at various classrooms where she introduced me to teachers and allowed me to see what was happening inside. As we walked, she pointed out prized features of the school building and grounds and she explained the contents of bulletin boards and student work on display. She gave me a history of the building and pointed out recent renovations. My public school tours were much shorter in comparison. Because their schedules were so busy, the two public school participants had little time to spend walking around. The brief tours Mary and Sandra gave me were very similar to each other and focused on the parts of the building they used or inhabited on a regular basis. We stopped at the main office and met the office staff and then toured their own classrooms. Both teachers pointed out the bathroom, the classrooms of one or two neighboring colleagues with whom they had close relationships, and one of the teachers let me know about a secret refrigerator stowed away in a classroom nearby where I could store my lunch if I wanted. All three tours provided food-for-thought about where each of the participants fit or believed themselves to fit into their school context.

Data Analysis

In keeping with a multiple-case study design (Yin, 2017), I used single case and cross-case analysis strategies. As I gathered data, I jotted notes in the data itself and transferred my notes to my research journal as part of the pre-coding process. This helped me keep in mind preliminary patterns in the data as they emerged, potential codes, and anything that struck me during the data collection process. As I transcribed my audio recordings, I made additional notes and composed analytic memos that connected potential codes with specific lines of data (Flick, 2014; Merriam & Tisdell, 2016; Saldaña, 2016). After I formatted and otherwise prepared my data for coding, I read through all of it entirely, as recommended in Saldana (2016) and made additional notes. When I was ready to begin the coding process, I grouped the interview data from each case (again, with each teacher serving as a case) and the field note data. I analyzed interview data for each of the three cases first and then I analyzed the field notes.

For my first cycle of coding, I used a combination of initial coding, attribute coding, structural coding, values coding, *in vivo* coding, and process coding (Saldana, 2016). I made a separate copy of each transcript and field note for each coding technique which resulted in me analyzing each piece of data multiple times. I used all techniques listed except initial coding for interview transcripts and all except *in vivo* for field notes. Initial coding allowed for an open-ended interpretation of data, while the other coding techniques directed my attention in more specific ways. With attribute coding, I focused on participant personal details and details about their teaching context. Structural coding focused my attention on the data that answered my research questions. Values coding, which draws attention to evidence of norms and beliefs, helped identify how personal values and cultural norms influenced the participants' decision-making. In vivo coding highlighted participants' own language choices in describing

phenomena, feelings, and ideas and helped keep me grounded in each participant's perspective. Process coding helped uncover the steps and processes participants followed to work through planning, implementing lessons, solving problems, giving feedback to students, and etcetera.

For my second cycle of coding, I used pattern coding (Saldana, 2016) to determine to look for patterns, categories, and themes in each case. Then I proceeded to cross-case analysis, where I used pattern coding to look for patterns, categories, and themes across the findings of all three cases and also noted when a case diverged from the others. As I drafted my findings, I went back into the data using theoretical coding. I applied *a priori* codes related to theories that could possibly shed some additional light on what I had found. I described the theories in Chapter 2.

Trustworthiness

Merriam and Tisdell (2016) indicated that to ensure trustworthiness in a qualitative research study, the researcher must conduct the investigation in a methodologically rigorous manner. Methodological rigor means the researcher has applied rigorous thinking to every step in the research proc**e**ss and done whatever possible to make sure the study is trustworthy. To safeguard trustworthiness in this study, I triangulated multiple sources of data and kept a research journal. Triangulation is the checking of information gathered using one data collection method against information gathered using a different method, for example, what someone reported in an interview should match what the researcher observed on site or check against what the same person said at a different time or place (Flick, 2014; Merriam & Tisdell, 2016). By keeping a research journal, I was able to maintain an audit trail of my thoughts, questions, concerns, and activities over the course of the data collection and analysis stages (Merriam & Tisdell, 2016; Ravitch & Carl, 2016; Rossman & Rallis, 2017). Being present, also known as adequate or prolonged engagement in data collection (Merriam & Tisdell, 2016; Rossman &

Rallis, 2017), is another strategy I used to enhance trustworthiness. This entailed making observations, conducting interviews, etc. until the same information began to emerge time and again and no new information surfaced with continued data collection. Saturating my body of data ensured that my findings were based on sufficient evidence, and that I made an effort to uncover refuting evidence. Peer review, or a university-based forum where I periodically shared my findings with my dissertation committee and/or a group of critical friends helped assess whether my data analysis was objective and my findings were plausible given the data collected (Merriam & Tisdell, 2016; Ravitch & Carl, 2016).

Ethics and Positionality

Before the start of data collection, I obtained approval from Montclair State University's Internal Review Board, which is a procedure intended to protect the interests of human research participants. The goal of this process is to protect those who might be vulnerable to exploitation. Ethical research that involves humans requires that consent be obtained from individual participants and, when research takes place within a school building or district, from the building or district leader as well. It is the researcher's responsibility to inform participants that their participation is voluntary and that they can withdraw from the study at any time. Participants must also be made to understand that they will suffer no repercussions for participating or withdrawing. It is also the researcher's responsibility to convey that all data collected will be kept strictly confidential, and measures will be taken to ensure that nothing participants say can be traced back to them.

During all parts of my data collection and analysis processes, I continued to consider how my positionality as a researcher might have influenced how I selected my participants, how I framed my questions, what data I chose to collect, and how I then interpreted the data. Because I

am a former teacher, I am able to gain access to schools and form connections with teachers relatively easily. From my research experiences, I know that teacher participants tend to relate to me as a fellow teacher, seemingly putting aside my role as researcher, and are likely to tell me things about their school and administrators that they might not mention if they believed I was in any way working in alliance with the school administration. Therefore, in the course of conducting this study, I remained ever vigilant about keeping the information I collected confidential. On the other hand, I was aware that having been a teacher and identifying with other teachers could limit my perspective at times, so I had to be careful to take detailed notes and write down everything I saw and heard in case over-familiarity rendered some teaching practices and routines invisible to me.

On the other hand, as someone who is a learner when it comes to The Maker Movement, making, and conducting research, I am aware that my developing understandings about making and my lack of experience in analyzing data might cause me to miss what otherwise might be important data or insights in the data. This is the main reason I chose to employ the constant comparative method of analysis, so that I could repeatedly return to the data, hopefully, with a more informed perspective each time. I was aware that my personal interest and enthusiasm about the Maker Movement, sparked by a fascination with 3D printers, as I mentioned earlier, might also predispose me to see only the good in maker education or interpret data with rose-colored glasses. Therefore, I remained extremely conscious of this possible bias to consider the full range of experience with making during data collection and data analysis. Finally, because the Maker Movement has historically been thought of as a tech-savvy-white-male environment (see Davies, 2017), as a female educational researcher and outsider, I believe I was able to remain open when examining maker education and Maker Movement influences on teaching,

because it is still somewhat foreign to me and at times teachers had to explain things to me. However, because of the implied exclusivity within the Maker Movement, I did have to control my bias and critical stance, as a non-tech-savvy white female, who is, in theory, excluded.

Chapter Summary

The purpose of this multiple case-study was to examine how three K-8 teachers think about and implement Maker Movement practices as they engage in making with students in the formal classroom setting and to understand how teachers negotiated the norms of the Maker Movement in relation to the norms of their school context and the norms of the general N-12 education context. I defined a case as a 'pioneer' teacher of students in the range of grade levels kindergarten through eight who is engaging students in making in his or her classroom. A pioneer teacher is one who has initiated making with students on a voluntary basis in the absence of whole-school or district goals to integrate making. Each case was bounded by the local school context and the three cases were nested within the larger contexts of N-12 education at the state and national level and the Maker Movement. "Mary" taught technology in a small public PreK-8 district where students progressed from Pre-Kindergarten to grade eight in one school building. "Sandra" taught STEM to grades six through eight in a public middle school that was part of a PreK-12 district. "Eli" taught fourth grade social studies at the K-5 Lower School site of a K-12 independent school.

I collected a range of evidence in relation to each case to create a rich body of data and allow for triangulation. Data included multiple participant-observation sessions documented with handwritten field notes and audio recordings; interviews with participants documented by audio recordings and handwritten notes; post-lesson debriefing meetings with participants documented

by audio recordings and notes; digital images and/or videos of classroom activity, classroom details, and teaching artifacts; and handwritten and audio documentation of building tours.

In keeping with a multiple-case study design (Yin, 2017), I used single case and cross-case analysis strategies. I used an iterative process, taking notes in the data and my research journal as I gathered and transcribed it and composing analytic memos that connected potential codes with specific lines of data. This allowed me to keep preliminary patterns and potential codes in mind. I used multiple coding techniques to analyze interview data and field note data for each case. During the first cycle of coding, I used attribute, structural, process, values, and *in vivo* coding for interviews and initial, structural, process, and values coding for field notes. During the second cycle, I used pattern coding for within-case analysis and pattern coding followed by theoretical coding with *a priori* codes for cross-case analysis.

In the following Chapters 4-6, I discuss my findings for each case beginning with Mary, followed by Sandra, and finally, Eli. In Chapter 7, I discuss my cross-case findings.

Chapter 4: Mary

School Context

"Mary" was the technology teacher in an upper middle-class, predominantly White, suburban PreK-8 public school district that served approximately 600 students. Mary's school was the only school building in the district. She described the school as having a cozy, nurturing feel that "was a lot like an independent school." The school consisted of several brick buildings—a series of additions—linked together so that they formed a rough B shape. The original building dated back to the 1930s. Except for two that had a second story added, the majority of the connected school buildings had one story. Inside, the hallways resembled a labyrinth. Classroom windows faced small grassy fields, landscaped courtyards, or parking areas. Built in a residential area, the front of the building faced single-family detached homes across the street. Graduates of the school attended a regional high school in another town that also served three other suburban PreK-8 districts. Students in grades PreK through five were grouped and scheduled in self-contained class cohorts while students in grades six through eight were scheduled for classes as individuals. The administrative team in Mary's building included the district superintendent, principal, assistant principal, director of curriculum and instruction, business administrator, and supervisor of special services. Five members served on the Board of Education.

Mary at Work with Students

In the following vignette, Mary introduces a new unit of study to a fourth grade class. She explains and demonstrates how to use Keva Planks and other materials to build a Rube Goldberg-inspired contraption. The week before, she had noticed that her fourth graders were getting tired of coding and, 'staying in tune with the frequency,' of her class, as she would say,

she decided to interrupt the coding unit for a hands-on activity that she believed would be more engaging. Standing in the front of the room, close to the tables (see Appendix B), she announced, “We’re going to take a break from digital literacy and do something hands on.” This created a buzz in the room. Mary started the lesson with “a warmup activity.” She handed out Keva Planks and directed students to hold one in their hands as they participated in defining what 3D means. “You can see from the sides… the top… straight on…” she advised. Mary went on to compare the six sides of a Keva Plank to a die and asked the fourth graders to imagine a number on each side. She explained what an “edge” was. Finally, Mary introduced the whole class activity: they must work with a partner to create a runway-type structure that a ball can run through.

> "You're going to work on building this [contraption] because then what you're going to do maybe next week and even into the following one is kind of build your own then, so this is going to kind of get you set up. So, what we have here are eight planks high. This here is six plank… I believe it's five or six planks high… and then two and then one no wait eight, four, two, one plank high. Then what we are in the center here are two planks wide with an upright and an upright on either side. A plank here, some dominoes. Then we have two planks high, a one, two, a bunch more that you'll be able to count, and then some standing. and you and a partner are going to construct this, and it has to be done on the floor because the tables move and you're putting things together. So, basically, what you're doing you're creating some runways for the balls to roll and do something, right?” (October 18, 2018).

Students paired up and each pair found a spot on the floor where they quickly got to work. In minutes, students had built their contraptions but then had to test them. One pair of girls found that their ball kept getting stuck in the same place. Mary, who had been rotating around the

room, eventually stopped and gave them some clues about how they might position planks so that the ball could push through more easily.

Throughout the lesson, Mary deftly balanced her identities as teacher and maker. First, by demonstrating how to use Keva Planks and providing other kinds of direction, Mary scaffolded her students' thinking. This way, they would not lose time trying to 'figure out' Keva Planks themselves and could instead begin to focus on the creative work of designing their own contraption. There are times when providing detailed instructions facilitates student thinking instead of over-directing it. Knowing how much information and support to provide requires an understanding of the students' zone of proximal development (see Vygotsky, 1978) and this requires effective formative assessment skills. In my view, from what I observed over the course of my visits, Mary was particularly good at setting her students up for success with clear directions and expectations. A sign was the level of enthusiasm and confidence with which students set to work, as if she had given them a pep talk. Mary's explanation of how to use the new materials and how to get started seemed to diminish the initial hesitation that some students can demonstrate when faced with the unfamiliar. In Mary's view, when the students were more comfortable and confident with the materials, they could make 'their own' mistakes and problem solve with their own designs. That, ultimately, was the learning goal. This first contraption was just for practice.

As I mentioned in Chapter 2, there is a common misconception (see Fontichiaro, 2018; see also Campos et al., 2019) that engaging students in making means simply providing the materials and tools and then leaving students to explore. This is known as "Magical Object Syndrome." In the above vignette, Mary demonstrated how her expertise as a teacher complemented her skills as a maker in the classroom setting. Mary also demonstrated flexibility

in meeting the varied learning needs of her students. During our post-lesson debriefing meeting, Mary mentioned that she was not planning to do a Keva Plank "warm up" with the next fourth grade group that day because they already had experience with them.

Mary's Background: Current Position, Education, and Early Career

Mary taught technology as a weekly special for grades three through five, an elective for grades six through eight and as enrichment for grades one and two. As an enrichment teacher, she worked with the homeroom teacher and class in their classroom. Students in grades three through eight met in Mary's technology classroom-cum-makerspace. Class sizes were standard for grades one through five but could vary widely in grades six through eight because, as I mentioned earlier, students were scheduled as individuals. Teaching was not Mary's first career choice: she had earned a teaching credential as an undergraduate at a large New Jersey state university "just in case [she] ever needed it" and then decided to fall back on it when the doctorate in sociology she was pursuing became financially untenable. At the time of this study, she had been teaching elementary school for nearly 25 years and had spent the majority of that time in her current position and school. Much earlier in her teaching career —in the mid 1990s— she had been a fifth grade science teacher in another suburban school district. When she accepted that position, she had no previous experience as a science teacher or background in science education. She learned on the job. It was in that fifth grade science teacher role that Mary first started making with students. The following sections help illustrate how Mary conceptualized making and first started including it as part of her classroom curriculum.

"Cobbling Together a Science Curriculum" Mary's Relationship to Curriculum and Making

In her first teaching position as a fifth grade science teacher, Mary recalled finding the textbook-based science curriculum unsatisfactory— "in those days [the textbook] *was* the curriculum...[T]he previous science teacher had just kind of had the kids read the textbook, answer the questions, and…move on. And... there were suggested experiments." Mary wanted her students involved in hands-on investigations, so she found herself drawing from a variety of resources that she purchased in teacher stores to "cobble together" a curriculum that was more hands-on and inquiry-based. "[I]n a way, I kind of was making my curriculum… So, like, tinkering with that and pulling the best things I could find and then making it my own and that's continued to this day." In her reflections, Mary emphasized this idea of pulling things together from various sources and repurposing them to align with her vision.

Eventually, Mary's district "formalized the curriculum" and adopted FOSS (Full Option Science System) as its elementary science program. What Mary meant by 'formalize' is that the district provided a framework of learning objectives for all science teachers in the district to follow. This action taken at the district level would make sense historically because the mid-1990s produced the first sets of national K-12 science learning standards (National Research Council, 1996b; Porter, 1994) that districts could use to frame their curriculum. The main goal of a district-level curriculum would be to facilitate an equitable education for students across the district. As Mary indicated, previously the only guidelines available to science teachers in her school were the contents of the textbook. Therefore, in Mary's elementary school, before there were national science standards, the textbook was the authority. Although many teachers today might still refer to a textbook program as a curriculum, others will say it is just a resource. In

some cases, it is a matter of perspective. For example, novice teachers might depend more on a teacher's manual and therefore think of it as the curriculum. However, more experienced teachers might be more aware of the formal district-level curriculum framework and allow themselves some latitude in how to implement it. How much freedom a teacher has, in this regard, would depend on the teacher's position and also the culture, climate, and mission of the school. Remedial reading teachers, for example, often follow highly structured protocols when working with students, such as *Orton-Gillingham* or *Reading Recovery*. As a novice teacher, Mary was already taking liberties with the science curriculum and using the textbook as little as possible.

Mary seemed to view a formalized district-level curriculum as a step in the right direction and she liked the FOSS program, which was hands-on and inquiry-based, as Mary preferred. FOSS is a kit-based program where all the materials for a unit of study come in a carton that can be easily stowed away when not in use. It saves teachers from having to gather the materials needed for students to engage in scientific investigations and provides the information needed for teachers to effectively facilitate. Mary credits FOSS' Models and Designs module as the best unit she has ever taught. "It was a science unit, however, it really, at the time, now this was in the 1990s, was very much an open-ended maker unit." As the outcome, students had to make a contraption, called a humdinger, that would hum and ding when someone pulled an attached string. The completed humdinger's inner workings were hidden inside a box. At the beginning of the unit, Mary presented her own completed humdinger to the class. The students, working in groups, had to imagine how Mary's humdinger worked and then figure out how to make their own from the materials Mary provided them. She added a step by requiring students to sketch out a rough plan before they could start building. Every group of students came up with their

own way to make a humdinger. As the unit came to a close, each student group presented its work and then Mary guided the class through a discussion where they compared and contrasted all the designs. In Mary's view, "it was the whole design process before it became very formalized for schools." Mary explained that FOSS modules were generally open-ended and exploratory, "which is what I really love."

"A Different Kind of Technology" Self-Authoring the Role of Technology Teacher

Mary left her fifth grade science position after a few years to teach technology in her current school district. When Mary first stepped into the role as the technology enrichment teacher for grades one through eight in the early 2000s, "not a lot of making went on." Until the Lego NXT Robot was released in 2006, Mary taught "primarily computer work" which was for the most part practice with Microsoft Office applications, such as PowerPoint. "[M]aker didn't exist as a whole thing at the time." Lego's original design for its Mindstorms NXT Robot was flawed, Mary recalled. The robots frequently fell apart and she found herself looking for a solution. "So, I kind of encouraged the kids to tinker with the design that was there so we could do robotics and not have these things break in two. And then… that…started to evolve into other things where I'm like, I have all these Lego boxes, let's start thinking about other things we could do with them."

At a certain point Mary found that students were coming to school with basic computer skills already in place. This was what first motivated Mary to add more hands-on making activities to her technology curriculum. She continued to teach coding on the computer, but she claimed that she and the students would quickly lose interest. "It's not very open ended in the same way that building with your hands is open ended." Mary also had to contend with a room full of ten year-old desktop computers that frequently broke down (see Appendix B). The final

push that motivated Mary to get her students off screen was, following the launch of the school's 1:1 laptop initiative, her observation that having their own Chromebooks significantly increased on-screen time across the day for students in grades five through eight. At that point, Mary replaced most of her computer-based curriculum with design and building activities so students could enjoy some social learning and practice "a different kind of technology." The students responded to the change with enthusiasm:

> You know, usually… they come running in. For the most part, they're like, "Can I get my stuff? Can I get my stuff?" because they just want to get started, you know?

Mary's responsiveness to student cues and her generative approach to teaching seemed to be strong motivators to include making in her curriculum. In other words, Mary did not decide to include making because she attended a professional development workshop that promoted making, other teachers were doing it, or an administrator suggested it. She decided to do it because it resonated with the way she liked to teach, and that seemed to be largely based on what she thought was best for kids. It also seems that adding making to her technology curriculum slightly changed how Mary viewed her teaching position. She was still the technology teacher, but now she was the teacher of a different kind of technology—technology that was more inclusive than what she was hired to teach.

Self-authoring theory (Bakhtin & Holquist, 1981; Holland et al., 2001) helps explain why Mary prioritized the cues from her students over the myriad other competing messages likely circulating in her school context, such as pressures from administrators to keep students on their Chromebooks, as she continued to develop her teaching self. It also helps explain Mary's innovative perspective on what technology class could include. In light of the pressures and goals of standards-based education, it is important to understand why a conscientious teacher like

Mary—whose work was formally framed by other authorities, such as a job description, an understanding of what a conventional technology teacher does, content standards, and supervisory feedback—would foreground her students' best interests when making decisions about her teaching practice. Self-authoring theory considers that the social and environmental cues one faces—in activities, in practice—are often in conflict with each other. In the process of authoring oneself, it is necessary to orchestrate conflicting cues. Therefore, one must selectively respond, ignore, or resist in the face of a cacophony of messages and perspectives to develop a stable authorial stance. Mary seemed to prioritize students' cues over those of the adults she worked with. I theorize that Mary selected the students' cues for two reasons: First, Mary cared about her students and believed that putting their best interests first was central to her role as a teacher. For example, Mary used a student-centered approach to teaching and learning and placed primary importance on how her students felt while they were in her class. Second, if Mary's technology curriculum were ever challenged by supervisors, parents, or colleagues, she could cite students' best interests as her rationale. Mary believed that her job as technology teacher was to help students develop skills "for the future of work." In Mary's view, no one could argue with that because in the context of the school, it is everyone's responsibility to put the best interests of the students first (National Policy Board for Educational Administration, n.d.). As a strategic navigator of the grammar of schooling (Tyack & Tobin, 1994), Mary seemed to have made it her business to understand not only her own responsibilities toward students but also her supervisors' responsibilities and used it as currency. The following sections will further illustrate Mary's authorial stance as a teacher who engages students in making.

"How Do I Make This My Own?" Conceptualizing Making and Teaching as *Remixing*

Just as she claimed she did in her earliest days of teaching when she was a fifth grade science teacher, in her current role as the technology teacher, Mary drew from a range of resources to cobble together a curriculum for each grade level that, ideally, engaged students in hands-on exploration and open-ended discovery. In her view, the academic curriculum that unfolded in other classrooms provided few substantial opportunities for students to engage in social learning, especially for her older students in grades five through eight:

> [T]he whole thing with makerspace, for me, was to try to remove kids from the computer...We do some [coding] and…we do the robotics coding more, so that's, like, real computer work... I just want kids not to be so interactive with a computer but to be more interactive with each other.

When she first learned about the Maker Movement and the reasoning behind it, Mary began to browse the Internet looking for ways to implement making in her classroom. "I was… looking for, well, where is… the how-to sheet for setting this thing up?" Discouraged, she lost interest in searching for a while. Later, when she started "skimming the Internet" again and found that "people were putting out ideas" and "all these…kits…jumping on the maker bandwagon," it occurred to her that if she started implementing making projects designed by others, it would defeat the whole purpose of a makerspace. "I thought… it's something…that I have to figure out even for myself. How am I a maker making a makerspace?"

Mary argued that making is mainly "remixing"—a word that describes how, it seems, she has always prepared for teaching:

> [Y]eah, it's great what other people are doing with [making], but I can't just take what other people are doing with it...the whole point of makerspace is making it work for you and where you are in the context you're in, and so, that's kind of what I did.

Mary was in the habit of planning for teaching quickly and informally, hoping to target student needs and interests that were specific to the group at hand:

> I can just pull something out if we need to pull it out, like this whole castle thing, I came up with this like…like I'm serious like it was probably the afternoon before you came in. It was like, I've got to do something with these kids, like, they're losing it with this coding. I have all this K'nex, what can I do with it? I looked a little online. It was like, meh. I don't like these lessons. This isn't me. But I like this idea. So, I then took an idea, ran with it, and then I, actually, even if you want to say I 'remixed,' from something I do with my 7th grade, and that's like this design process because I like design, and it's like oh, let me… Eh, they could make castles.

Mary observed that whenever she first explained remixing to a group of students, they hesitated to borrow other's ideas because they thought of it as stealing. Students had been conditioned throughout their years in school not to copy, download, or reuse content without paying or citing it as a source. They thought in terms of anti-plagiarism policies. Mary indicated that it could take a while for some students to resolve the cognitive dissonance and accept that it was okay to base their work on someone else's or let others use their ideas. Some students might be indignant at first because they firmly believed that copying was wrong; or they could be competitive and want to retain credit for the idea. When Mary noticed that students were concerned in one way or another about remixing, she advised them to take it as a compliment—"that somebody did something so cool that… they are allowing you… to take it and make it cooler or make it better

for *you*…" In general, she used encouragement and an expectation of generosity to help students get past their anxieties:

> [O]nce [when students were working on those castles with me] a kid got a peaked roof… [O]ther kids saw it and I said, "Well, go over and find out how he did it!" And…the kid who…made it first was like, "Ugh, they're coming," I'm like, "Yeah, let them figure that out—or show them!"

Mary used *Hour of Code* each year to encourage remixing. *Hour of Code* is an annual digital event in December, provided by the non-profit Code.org. Mary recalled having her fourth graders participate in an *Hour of Code* project called "Dance Party," which she thought was "phenomenal." In "Dance Party," as with all the *Hour of Code* events, students could look to see what other students around the world had posted as public projects. They could then take a public project, press the "remix" button, go in, and tweak. In "Dance Party," "[t]here's…this… dance video. You bring all these characters in, you know, the animated characters, and have them do different moves, different timing, different backgrounds. It's very involved and intricate." Although Mary's fourth graders lacked the coding ability to initiate a "Dance Party" project, she thought it was a great opportunity for them to use what they did know about coding to practice remixing. She encouraged them to look at what the eighteen year-olds were doing, find a public "Dance Party" project they liked, and tweak it to make it their own.

> [S]ome of the kids were saying, well isn't that copying? …[T]hat's, like, acceptable use and digital citizenship. And I'm like no, *Hour of Code* is encouraging you to remix things that are good so you're not copying…it's ok to do this. It's very collaborative, it's a way for you to learn...So, yesterday, we had kids…remixing! I mean, there are hundreds and hundreds of these videos posted…and they're remixing all the codes.

Mary's maker mantra for herself and her students is: What ideas do I like? How could I make this idea better? How could I make it like [that other person's], but with my own twist on it? According to Mary, there was no competition in making.

"It's Based on the Materials" How the Availability and Management of Materials Factor into Engaging Students in Making

Mary claimed that her curriculum was based on the materials she had available. These materials included building blocks such as Legos, K'NEX, and Keva Planks as well as online "materials" such as a subscription to Code Monkey (see Appendix C). When planning, she always started with the materials, thinking, how can this/these be used in an activity or project that will extend over days or weeks. "A lot of effort goes into a one-day lesson and so I don't make one-day lessons." Student work would continue with the materials until Mary saw that the students were getting tired of it and then she would know "it's time; it's over."

Despite the image of making as technology-infused, Mary discovered that it really comes down to having "stuff" available. "[J]ust stuff that maybe kids have played with as children." She had seen images of makerspaces online, many of which were tool-oriented with students handling saws and drills, for example. Mary was not interested in tools like that and "the situation [she was] in" she could not set up a woodshop in her classroom. Mary preferred "the toys." She filled her classroom with materials that her students might have grown up playing with at home, like Legos, Lego bricks, and K'NEX.

> I think there are different kinds of makerspaces that reflect the teachers who are designing that space...I like to look at mine as…a little more artsy, creative design oriented...But not mechanical. And not like a shop...I want mine to be more like, you

> know, play time <laughs>. “Come in and play!” Rather than, “Come in and you have to learn how to operate the drill.”

As I suggested earlier, self-authoring theory asserts that “[b]ehavior is mediated by senses of self or what we call identities" (Holland et al., 2001, p. 214). Mary’s vision for her makerspace seemed to reflect what I contend to be her identities as a caring, trustworthy guide and a social constructivist. She placed priority on how she and her students felt while working in the space and how students connected with it as learners because she understood the relationship between positive emotions and learning (Meilleur, 2019). Therefore, rather than present making as an introduction to tools and materials that her students would likely find less accessible, she presented it as an opportunity to be creative with the familiar and, perhaps, beloved (see Appendix C).

Mary acknowledged that many of the classroom makerspaces she had read about included at least one 3D printer. She was not a fan of using 3D printers to teach making because 3D printing was time consuming and difficult to manage logistically. Also, the work involved in creating a 3D model, in her view, was not as open-ended and spontaneous as simply building with one’s hands. “You need, like, a 3D printer for almost every computer…because it takes three hours to print something…People love the 3D printer, but once the [student prints the CAD file] you're done.” The projects made with K’nex, Legos, Keva Planks—students could keep adding on to them in real time.

Mary claimed that her instructional strategies were the same as what teachers in other content areas might use, but “when your classroom is a makerspace, supply management is key.” She knew her supplies and could often visualize exactly what Lego piece, for example, a student

needed to solve a design problem. To protect her supply, she constantly took inventory and placed a lot of importance on cleanup time at the end of each class:

> You know, clean up, like, try to, you know, stop class ahead of time, check the floor.. I have a little Lego game where I check… and I put on an act, and I'm checking the floor. You know, if a piece of Lego is in the vicinity of these two tables the two tables get detention, but they never do <laughs> because I'm not like that, you know. I was like, okay, I'll let you go today, so... <laughs> You know? You get detention over Lego on the floor, but, you know, it's a game and it's like, "Oh, oh, oh, I see it!" I give them a second; they run, and they jump on it, and they grab it, like, dodged that bullet! (Mary).

Mary acquired a lot of her materials by applying for grants from her school district's parent-run education foundation.

"It's Very Contextualized" Balancing Student and School Factors to Make Decisions

In Mary's view, the whole point of a makerspace was "making it work for you and where you are in the context you're in." In terms of lesson planning, it all depended on the group. Mary designed what she called "amorphous units" that could, conceivably, go on endlessly. She would introduce a unit of study to all groups in a particular grade level, but if any group decided they would rather do something else, Mary was willing to turn on a dime and develop a unit based on student input:

> I go into the year, yeah I want to do this, this, and this, and I try this this and this, and then sometimes I find that the first this <laughs>... doesn't work, or I'm not getting a good vibe from the kids, so then we bag it and then we move on. [A]gain, you know, it's very contextualized… to the students in the class and where they are and also their feedback.

Although she believed her amorphous unit approach worked best for her students, Mary was self-critical about her curriculum planning habits. As a maker, she felt uncomfortable with the idea of designing and planning student learning experiences in advance; however, as a teacher she felt she was expected to do so. Mary explained the challenges this created for her:

> [B]ecause what I do is so open ended, and my philosophy is so open ended, I have a very hard time… formalizing it as a curriculum in terms of assessments and lesson plans and... time... Like, when the kids come in my room from a traditional classroom or a subject area class, it's a different time structure, curriculum structure, and it's almost… in a way I try to liken it to 'This is what... their future is going to look like.' They're going to walk into a place and that's going to be like, ok I guess I got to do that now and, like, I guess I have a really hard time formalizing this.

Mary also felt uncomfortable with the idea of grading her students' making projects because she believed giving grades could discourage risk-taking. Nonetheless, she was required to submit grades for report cards. Consequently, she based students' grades mainly on attitude, giving students credit for demonstrating high levels of interest, motivation, and signs that they were developing self-efficacy:

> I take a lot in with student engagement and what they're doing and then assessing are the kids working? Are they behaving? Are they engaged? Are they asking me questions? And then I throw the grades on the report card from the top of my head. Don't tell anyone I do that! <laughs>.

With that said, Mary regretted having to end class at the end of the allotted 45-minutes when students were still so deeply involved in their work:

> When it's three o'clock in here and the kids don't want to leave, I mean, that says a lot. And I've gotten compliments from the teachers too about… when they come to pick up their kids, you know, the younger ones, like, they're so… They walk in and like… the kids are somewhere else. Like, they're in the zone, you know, and it's like, guys, you gotta, we got to go! and they're not cleaning up.

Mary also regretted not having the kind of classroom space that would support the kind of making she aspired to do with her students. A lack of storage space for materials and ongoing student projects limited the functionality of her room. Mary had entertained (and given up) the idea of setting up stations in her classroom, thinking it might solve some of her space issues:

> Mary: I would love to have kids involved in, in one sense like, station work... I would set it up as centers where there would be multiple things happening at the same time rather than everybody doing the same thing at the same time. Maybe a little more interest driven on the student's part, where maybe kids want to do coding, kids want to do more building, kids want to try out the 3D printer. But rather than everybody doing lockstep the same thing, it would be a more interest driven, you know, center-focused kind of classroom or curriculum. You know, what they'd be making. Obviously, I like the things I'm working with, the robotics and all that, but I almost would like to kind of gauge from the kids, what is it you'd like to try out? But the problem is because I work with so many different grade levels, organization-wise that would be a nightmare for me. So, this is why we kind of do things lockstep.
>
> Me: So, do you feel limited by the space itself?
>
> Mary: I do.
>
> Me: the space alone or are there other things…?

> Mary: Space and the schedule and the number of classes I teach [and] the grade levels I teach. You know, so yeah, so I mean I almost wish, like, I could have one or two grade levels and, but that's not going to work so.. I mean, I don't even see the whole school as it is, you know, there are some kids who don't even get this at all, you know, kindergarten through 2nd grade, so…

Over the years, Mary had put a lot of thought into how she could use her classroom space to maximize student choice but was unable to find a workable solution. Mary wanted the student making that took place in her classroom to be student directed and open ended, however, the constraints of school structures such as the schedule, classroom space, and availability or feasibility of materials and tools seemed to limit how student-centered Mary could be in her approach to making. It seemed that Mary could work around some other school structures to support making, such as curriculum planning and assessment routines. However, working around school structures required professional risk-taking and, for Mary, this created feelings of anxiety. These are all examples of how the grammar of schooling (Tyack & Tobin, 1994) influences teacher decisions.

"It's the Soft Skills" Filling a School Curriculum Gap by Foregrounding Social Learning Skills

Mary placed more value on what she called "soft skills" than almost any other learning outcome in the makerspace setting.

> [T]his year I've probably done more making than I've ever done... [I've] become a little more aware of, organically, what making…is, how important it is, and how little of it [students] get in school. And the kinds of skills that it brings... while you're making something.. What's going into the making, which is probably even more important than

> the making. Because what goes into it is timeless... It doesn't become obsolete: communicating with someone or working together, having a plan, having end results, you know…[S]oft skills as I like to call them…and I think...this year I've been trying to focus on those soft skills rather than on the skill of the technology or the thing you're making…

As I mentioned earlier, Mary's primary goal in shifting from a computer-based technology curriculum to an off-screen hands-on technology curriculum was to foster social learning. Her reasoning was that many of her students were not getting a chance to practice communicative, collaborative, or executive skills such as planning and goal setting anywhere else.

Following the launch of a 1:1 laptop initiative in grades five through eight, Mary noticed that students had become more interactive with their screens than with each other. She also observed that the typical activity that most academic teachers seemed to assign was "just a worksheet on a computer—souped up worksheets." She decided it was in her students' best interest to put the Chromebooks away and practice "a different kind of technology" in her room.

> When I have kids on the floor working together, who are in eighth grade…and they don't care if they're getting their pants dirty, that's a good thing. And they're socializing and…developing soft skills—that they don't have a chance to now practice really anywhere—and... I think it's these soft skills that are going to move them through, you know. Listening…and speaking clearly and being clear in your intentions and…thinking a little bit out of the box... I think that's what's…going on and I'm shifting as well.

Mary acknowledged that the new science curriculum her district had recently adopted was "very inquiry based." The Next Generation Science Standards it was meant to align with fostered collaboration and exploratory learning. However, Mary argued, "that was science." What she was doing with her students was "this other thing." It was more social, more creative,

more design oriented, and as she implemented making with students she was "thinking in different ways how things connect."

Mary also connected student development of soft skills with social-emotional learning and student wellbeing. As I mentioned earlier, Mary seemed to connect student readiness to learn with their emotional state:

> [I]t's more about...coming in here and making it, like…an older form of kindergarten. And the kids love it, you know. They love coming here... [There's] a class called 'wellness' that's run by the health teacher...One kid just summed it up. He said, "This class should be called Wellness" <laughs>. He said, "Because we get to relax, we get to talk, we get to work with each other...and just gonna do. And you come in and it's fun."

"I Don't Have a Curriculum—at All" How the Need for External Validation Influences Teacher Decision-Making

As I mentioned in a previous section, there are many different ways to interpret the word "curriculum." Most of the time during our conversations, when Mary referred to "the curriculum" she meant 'district-level curriculum.' Neither Mary's PreK-8 district, nor its affiliated regional high school district had ever created a district-level curriculum for technology. So, although Mary appeared to have a curriculum that she implemented each day in her classes, she did not see it that way. In her view, she was "just making it up." To Mary, her classroom curriculum was not the authority: the district-level curriculum was the final authority. Mary highly valued—and protected—her professional autonomy as a teacher and curriculum designer in the classroom, and she used state technology standards as a way to validate her lesson plans if administrators should pay a visit:

> [T]here're some state [technology] standards but, like, you know, whatever, the kids meet them every day, as far as I'm concerned, with me. Stupid technology standards that...haven't been upgraded since 2014… (Mary).

Yet, without a district-level curriculum Mary felt anxious that she might be under-serving her students.

> Sometimes I see myself as a fraud. Like, I'm a fraud. …[Y]ou know… there's that thing called impostor syndrome? And I kind of see that in absolutely everything I do. Like, I'm making this [stuff] up. I'm, I really, you know I, I know rationally I have the skills but a lot of times, like, I kind of don't think I do. …

This ambivalent stance toward planned curriculum, I argue, is an indicator of Mary's identity development as a teacher who was engaging students in making:

> A first step toward an authorial stance...is the creation of internally persuasive discourses—external or authoritative speech that has been married to one's own (Holland et al., 2001, p. 214).

I posit that Mary had not yet gained enough confidence in her own authority as a maker or implementer of making in the classroom or in how well her efforts were serving her students as learners to reject the school district's authority when it came to curriculum. Unfortunately, there is a lack of scholarship on the relationship between making and learning outcomes (Lindsey & DeCillis, 2017; Vongkulluksn et al., 2018) so, if asked to justify engaging students in making based on its contribution to academic outcomes, Mary would have had nothing helpful to refer to. Alas, because N-12 education seems to habitually look outside itself for verification due to its "historical institutionalization as a feminized, weak, bureaucratically-administered field" (Mehta,

2013a), Mary's own observations and analysis could very well have been vulnerable to outside scrutiny and doubt.

Further, there was no one else in the district besides Mary who could evaluate the content or vertical trajectory of her program to determine how it fit with the kinds of making students might be doing in the high school. Mary was the only technology teacher, and, Mary indicated, the Director of Curriculum and Instruction was "focused on academics." What made Mary's situation possibly more difficult was that the regional high school was in a different town and run by a different superintendent. Mary's PreK-8 district was just one of several "feeder districts" that sent students to the regional high school. Mary explained that although there was some collaboration among the PreK-8 districts in curriculum planning, it was unclear how best to prepare students for the technology program at the high school. As Mary mentioned, her Director of Curriculum and Instruction was focused on academic subjects such as language arts, science, and math. An unfortunate side-effect of standards-based education reform is the external pressure placed on public schools that diverts attention and other resources away from low-stakes subjects, such as technology, in favor of core academics and, in effect, marginalizes them (Spillane et al., 2011). It appears that as a teacher of a marginalized subject, Mary had been somewhat marginalized as well.

Another complication for Mary's curriculum situation was that the other feeder districts were configured differently than Mary's, which influenced scheduling, course offerings, and course content. Mary's PreK-8 district was the only one with a single school building: each of the other districts had one or more PreK-5 buildings and a separate middle school for grades 6-8. Mary described some of the other middle school technology teachers in the other districts as having multiple certifications, including woodshop, and more extensive training in robotics than

she had. Many of the other districts' elementary schools had libraries with makerspaces in them. Mary knew this mainly by reading about these other schools online. She believed that it was likely that the other districts were providing students with a wider range of technology and making experiences than she was. Especially concerning to Mary was that some of these districts promoted their technology programs as "top" and also seemed to foreground robotics as making.

> I don't know. I think this maybe also goes back to me making it up, like… I'm not technically planning way ahead of time. So, I feel like… my planning falls a little bit short. I mean… But I do a lot of things, like, it's… spur of the moment. And… just trying to, you know, cover my tracks. But I sometimes feel…While I said that I don't think just anyone can come in here and do this, sometimes I think someone can come in here and do this a hell of a lot better than me. And that's probably what it is. Someone who has more robotics experience, more coding experience than I do. I mean, I don't have a background in this stuff.

The lack of curricular alignment in making among these feeder districts combined with Mary's awareness of her unchecked professional autonomy left her feeling very uncertain about her program. As indicated earlier, she said she often felt like a fraud and feared that one day a new administrator would come along and expose her as "the fraud that [she was]."

> I fear the day when I lose the administrative team that we have and I get someone who's going to be on my [back] and be like, "[What's going on here]? ...They're making castles?! … [T]hey should be exploring...the mathematical formulas behind [x]!" ... and really make this more academic than what it is… because… right now, while it is academic, that's kind of a lesser focus than bringing your ideas together.

In sum, what Mary seemed to want, and lacked, was some form of external validation for her curriculum. Without a district-level technology curriculum to refer to or a community of practice (see Wenger, 2011) to share responsibility for curriculum development and serve as a means of support, Mary had no one to turn to if a school constituent were to turn a critical eye on her curriculum choices. As I mentioned earlier, it is not uncommon for N-12 teachers to fear having their practice questioned because they are not consistently treated as professionals (Bruno, 2018). Mehta's (2013a) penetration of technocratic logic theory suggested that public education has been historically structured as a public bureaucracy controlling a weak profession. It theorized that teaching is vulnerable to external control because it was traditionally considered women's work that needed men to manage it. This history of being bureaucratically controlled, both within the school and state contexts, has made it difficult for teaching to achieve professional status. It seems that the current standards-based education reform movement has further undermined teachers' professional status and left many feeling devalued (see Bruno, 2018).

Mary did not dwell on feelings of inadequacy while she was teaching, nor did she put pressure on herself to know everything there was to know about teaching making. If, for example, students asked questions that pushed up against the limits of her robotics knowledge, she would enlist student experts to help answer these questions. One of Mary's favorite teaching strategies was to "broker" knowledge by connecting students with each other. "Hey, go to that guy because they know [the answer]." It is not uncommon to have students who teach themselves skills and concepts that go beyond the curriculum in certain areas of special interest to them, and in Mary's class, these students sometimes became informal teachers. Encouraging students to seek help from peers enabled Mary to distribute teaching and learning in her classroom, which increased the *flow of information* throughout the group (see Brown et al.,

2010). Mary believed social learning of this nature contributed to community building in the classroom. In her view, it also aligned with Maker Movement practices.

Despite Mary's doubts about her curriculum, she still preferred it to any other option she might have imagined. This, again, relates to self-authoring theory, which contends that "in the course of local struggles, [the] marginalized...create their own practices. [They are] identified by these practices and often identify themselves as 'owners' of them" (Holland and Lave, 2001, p. 19). As I mentioned earlier, Mary based her curriculum on the materials available and student readiness. She had observed over the years that a lot of students came to school with little to no experience building or working with their hands. Knowing this, she tried to make it as appealing and accessible as possible:

> If you do try to make it more sterile in a way, I think it can frighten kids and frankly turn them off. I mean, it's good to see that, honestly, for the most part every kid that I've ever taught has enjoyed my class. Honestly. You know… But is it because...Is it too easy?

Although Mary would argue for her approach to making over the way it was done in the other schools, she fretted over whether she had hit the right balance of engagement and appropriate challenge with her curriculum. Adding unfamiliar materials and tools, like saws, drills, 3D printers, Raspberry Pis and Arduinos; adding more explicit academic content, such as math or science concepts; or increasing the focus on robotics could certainly contribute new learning opportunities and challenges for students, as the Maker Movement literature has argued (e.g., Bevan et al., 2014; Eisenberg & Beuchley, 2008), but as I indicated earlier, Mary doubted this kind of new learning would contribute much to skills that she valued more, such as remixing and hands-on iterative problem-solving. In fact, she believed the addition of too many new tools and concepts could possibly intimidate students and shut them down or require so much frontloading

there would be less time for creative application and critical thinking—the skills that she believed to be the main benefit of making. Mary's makerspace invited students to 'come as you are.' This, I argue, is more evidence of a developing authorial stance (Holland et al., 2001). Despite evidently feeling as though she were taking a professional risk, Mary seemed willing to defend her teaching choices if compared with those of her peers or with claims in the Maker Movement literature.

"They Have No Idea What I Do in Here" A Disconnect between School Leadership and Teacher Development

Mary was convinced that her administrators could not really comprehend or appreciate her teaching. As I mentioned earlier, she took this stance because there was no district-assigned curriculum for her technology course that administrators could reference. In addition to that, they rarely observed her. These factors, Mary believed, left administrators ill-equipped to evaluate her practice or provide useful feedback. During an interview in mid-December, Mary remarked that despite an eight-observations-per-year protocol, no one had been in to observe her yet that year. She predicted that all her observations would take place at the end of the school year "when they're rushing to get them done, because that's what happens every year to me." As a result, she felt somewhat taken for granted and vulnerable at the same time.

> [My administrators] don't even ask me…about [my teaching] and I'm fine with that…but…in a way, I mean…I do some really cool stuff and I wish someone else could see it too. [S]o in a way… I almost wish they came in but then again...why are they going to waste their time on me when you have.. "Joe Schmo" down the hall who's...screwing up all the time. So, they're going to go down there…[T]hey kind of pick their battles.

During interviews, Mary exhibited conflicting attitudes of anxiety and confident defiance when she discussed curriculum and teaching decisions she made in her classroom. She suggested that she suffers from "imposter syndrome" as she described feeling like a fraud and worried about "being exposed" by some possible future administrator. However, it was also evident to me, as I have mentioned, that she valued her autonomy and would do whatever she thought necessary to protect it. For example, Mary described how she (consciously or unconsciously) seemed to work hard to ensure the trust of her supervisors by always "[doing] something great with the kids." As long as the projects Mary engaged the students in looked good, received positive feedback from students and parents, students seemed to be having a good time, and there were no parent complaints, Mary's administrators left her alone. She claimed that she never let any student leave her classroom feeling frustrated or upset, and that was key to keeping a low profile. "My administration: they have no idea what goes on in this room. They [don't care], quite honestly, as long as the kids leave here happy, and they don't get parent phone calls."

Mary was very conscious of optics and, whenever possible, made sure to post a couple of New Jersey state content standards on her Google Classroom for the days' lessons and display them on the Smart Board, "so that.. it [looked] like.. [she was] doing what [she was] supposed to be doing." Mary explained that it worked to her advantage if she "played the game" of lip service to mandated practices. She made it look like she was aligning with standards "just so that the [administration] can check off things on their list." As long as Mary's administrators could see everything they needed to see on the rare occasion that they stopped by, they were content to treat Mary with benign neglect. This is another indication of Mary's self-authoring process. It is also an example of Holland and et al.'s (2001) history-in-person, which theorized that "local contentious practices are the sites of complex mediations between intimate, interiorized practices

of identity, on the one hand, and, on the other [enduring social, cultural, economic, or political struggles].” In other words, Mary’s identity as a technology teacher who engaged students in making was being forged and solidified as she, consciously or unconsciously, pushed back against nested authorities. The nested authorities included her administrators’ compliance with state regulations and the standards-based reform movement that, as Mehta (2013a) argued, in a more indirect way, robbed Mary of her professional authority (see also Bruno, 2018; Spillane et al., 2011).

As Mary engaged in ‘playing the game’ to protect her practices, she wavered between wanting closer and more engaged supervision and wishing to keep a low profile. Regular observations and interactions with administrators could have potentially resulted in positive feedback for Mary, which would have been validating and “nice to hear.” As it was, though, she suspected her administrators lacked a full understanding of what technology was and therefore were not equipped to provide substantive feedback.

> [M]y colleague next door who's the music teacher... and we have the art teacher over here...we're kind of the weird wing that nobody really wants to even go there, you know?

Instead of closely monitoring Mary’s teaching, it seemed that Mary’s administrators worked under the assumptions that she was doing a good job and that she knew she was doing a good job, and therefore nothing needed to be said. As a result of this benign neglect, Mary felt left out on a limb. Nevertheless, Mary anticipated that closer supervision would likely invite unwanted interference. She wanted to “fly under the radar” so she could continue to make her own decisions about her teaching practice and her makerspace. Mary believed she was in a unique position to understand what her students needed and that maintaining an arm’s length

relationship with administrators was probably necessary to protect the qualities in her technology course that she and her students seemed to value.

Chapter Summary

Mary conceptualized making as remixing and encouraged her students to build on or revise the ideas of others. She made making accessible to students in her technology classes by including open-ended materials such as Legos, Keva Planks, and K'nex. She believed that these familiar "toys" provided a scaffold for creative and critical thinking and fostered learning through play. Over the course of twenty years, Mary had transformed her technology content from "basic Microsoft Office skills" to coding and robotics—or "real" computer skills—and hands-on building projects that emphasized design and problem solving. She accelerated the shift to hands-on technology learning when she observed that a 1:1 laptop initiative significantly increased on-screen time for fifth through eighth grade students across the school day. I argue that Mary's decision to teach "a different kind of technology," precipitated a period of identity development, or self-authoring (Bakhtin & Holquist, 1981), because it was inspired by her own assessment of what served the future best interests of her students. In addition, I suggest that Mary began to engage in contentious practices (Holland et al., 2001) when she turned her technology lab into a makerspace. Although Mary seemed to have tacit administrative approval, the informality of her technology curriculum, with no district-level technology curriculum to use as an anchor, placed her at risk for future criticism or censure. However, Mary was a savvy navigator of the grammar of schooling (Tyack & Tobin, 1994). Confident in her judgment that her updated technology content was more relevant to what students needed today, Mary felt she could defend her curriculum with the argument that she was "doing the right thing" to prepare students for the "future of work." Mary also believed that the particular ways in which she

engaged students in making were the most age-appropriate for her students, and she made most curricular choices based on how students responded. Interestingly, as confident as Mary was in her teaching choices, without a district-level technology curriculum or any degree of inter-district curriculum alignment among the regional high school feeder districts, she was fearful that she might somehow be under-serving her students. Mary doubted whether she was teaching "maker stuff" well enough, especially robotics, and she felt stressed about having to "make up stuff all the time." The hands-off supervisory style of her school administrators exacerbated Mary's anxiety because it left her feeling unsupported and "out on a limb." Mary believed administrators spent minimal time in her room because they had total trust in her, but, I argue, it was also likely that technology was a low-priority subject from a standards-based school reform perspective (Spillane et al., 2011). As Mary said, "they put out the big fires first." Therefore, Mary was somewhat marginalized by a lack of supervision.

Nevertheless, Mary took it upon herself to stay informed about the school curriculum at large and aware of what her students were learning in their other classes. She used this knowledge to inform her teaching choices. Accordingly, Mary used her technology curriculum as a balance for the demands and gaps in learning created by her students' academic courses. She cultivated a relaxed atmosphere where students could socialize and engage in informal social learning and she foregrounded the development of "soft skills," such as listening, communicating clearly, and thinking creatively.

Chapter 5: Sandra

School Context

"Sandra" was the middle school STEM teacher in an upper middle-class, predominantly White, suburban PreK-12 public school district. Sandra's middle school building served approximately 800 students in grades six through eight. The district's four other buildings were each dedicated to a small group of grade levels: one served PreK through second grade, another served third grade, yet another was for fourth and fifth grade, and, finally, the high school served ninth through twelfth grade. Therefore, students moved in cohorts from school to school. The middle school building, set on a mountain side among grassy fields and a backdrop of trees, resembled a modernized version of a medieval fortress. It was two stories high with a basement floor. The administrative team included the principal and two assistant principals. The district superintendent and business administrator's offices were located at the third grade building. Nine members served on the Board of Education.

Sandra at Work with Students

In the following vignette, Sandra stops to check in with small groups of eighth grade students as they work on a roller coaster design challenge. All around Sandra, the room was a-buzz with chatter and activity. Groups were spread out among seven different tables (see Appendix D). Students were cutting, folding, and taping paper and cardboard to create columns and diagonal supports for the roller coaster track. Due to ongoing behavioral issues, Sandra had limited this group to projects that did not require saws or knives.

Sandra: How are you ladies doing?

Student 1: Good.

The girls had been working together cheerfully, enjoying each other's company.

Sandra: Good? Alright. Working on diagonals? We had to…revise our plan a little bit last class. Did you fill "Lily" in?

Student 1: Yes.

Student 1 seemed to be serving as the spokesperson for the group while the others leaned over the table and looked quietly on.

Sandra: Yeah, so… Lily they were uh did you tell her about overlapping on the columns? Or no?

Student 1: No.

Sandra decided to explain it to Lily, who had been absent, herself. Sandra pointed to one of the roller coaster supports, taped to a large sheet of paper, with her pen.

Sandra: If you look Lily, there's…it needs some support and so to get it a little bit stronger it would be better if it was overlapped a little bit, so we kind of came up with a solution…that I think the girls could show you that will help with that first sturdiness.

Suddenly, there was a commotion and we all looked over to a table nearby to see a large group of boys gathered around someone's project that had been placed on the floor and flipped over onto its columns so that it looked like a table. Another boy had grabbed a roll of tape from the girls' table and gleefully placed it on the overturned project to see if it could support the tape's weight.

Sandra: <Addressed the boy, Student 2, who took the tape> What was that? Why did you take it from their table?

He gave Sandra an innocent look.

Student 2: It seems like they're done with it since they're drawing.

Sandra: Okay… <Then she addressed another boy who had just placed a triangle ruler on the overturned project to go with the tape> What are you doing? That ruler's for measuring. <She said to the girls> I don't know why he took the tape. <Sandra spots a roll of tape lying at the end of a nearby table and grabs it> Here's another one. Okay. Alright. If someone needs tape would it be okay to share since you girls have two?

Student 3: Yeah.

Sandra: Okay.

<Moves to a new table>

Sandra stops at a table where five boys are working together. They were drawing the shapes they would need to make roller coaster parts. One boy was trying to decide how long to make his lines.

Sandra: How tall is it?

Student 4 ("Brent"): It's not 36, it's less than that.

Sandra saw that he had made additional drawings.

Sandra: What are they? Ah. The diagonal supports. You're actually using the T-square, Brent.

The boys all look over at him. He had been busy measuring. Brent looks up.

Student 6: Giggles.

Brent: Is that bad?

Sandra: No, that's good.

Student 6: [Laughs] Finally.

Throughout the class, we had observed several boys playing with the flexible T squares, waving them around in the air and slapping them against their stools.

Sandra: I didn't…I haven't seen anybody actually really using it for what it was intended. So, nice. Nice parallel lines, right?

Student 6: Giggles.

Brent: Sho…

He kept working and answered her without looking up.

Sandra: Yeah, I think the diagonals are a little trickier to do. And the horizontals are going to be like the columns. They hold that whole structure together.

A boy at the table asked an inaudible question. There was a lot of chatter at surrounding tables.

Sandra: What?... I think there are only three on this one.

<Moves to new table>

Sandra arrives at another table of boys. (There were six girls in this class and thirteen boys). This was one of the tables where boys were fooling around with the T squares. It seemed that the boys had divided the work so that one was drawing and others were waiting to cut and fold.

Sandra: Alright, what are you boys working on?

Student 7 ("Nick"): We already have got two pillars done… today.

Sandra: Nice.

Student 8: Yeahhh! <Stands at a small distance from the table observing. Throws pencil up in the air and catches it.>

Sandra: How many were we going to get done?

Nick: Six. <Wiggling in his stool.>

Sandra: Oh, you can do more than six. You've got to move this along. Nick, would you keep the stool still? Thank you.

Sandra: Alright…A ruler might be good too.

Nick: For what?

Sandra: For measuring.

The above vignette, which captured just a few minutes of instructional time, characterized Sandra's teaching style. Sandra usually began by questioning students to clarify what they were doing and then provided students with instruction as needed. In this vignette, she provided some math instruction, including geometry and measurement, in addition to problem-solving suggestions. The varied nature of Sandra's teaching points illustrated the interdisciplinary and spontaneous nature of makerspace teaching and learning. Sandra also managed student behavior by, for example, urging a student that she was coaching to stay focused and keep pace while also redirecting other kinds of student behavior happening in other parts of the room that she perceived as off-task or otherwise inappropriate, for example, when a student grabbed a roll of tape from another group. Effective management of small groups and the whole class at the same time requires situational awareness, among other skills. Sandra was able to remain aware of individual students and the whole class at the same time, remain calm, and quietly address issues as they arose. This vignette portrayed some issues that can arise when students are using unfamiliar tools. Sandra jokingly complimented a student for appropriately using a T-square because other students had been fooling around with them by waving or twirling them in the air, pretending they were swords, or slapping them against their stools. Sandra opted to use behavior-specific positive reinforcement as a strategy to help diminish the

behavior (see U.S. Department of Education, Institute of Education Sciences, n.d.). With eighth grade students, it seemed that Sandra felt comfortable employing some light sarcasm.

Sandra's Background: Current Position, Education, and Early Career

Sandra's STEM class is a semester-long elective offered to grades six, seven, and eight. The STEM curriculum builds vertically from one grade level to the next, and students attend Sandra's class with grade level peers. Sixth and seventh graders attend STEM class every other day for one semester per year and eighth graders attend every day, also for one semester per year. Students may register for STEM each year; however, they are not required to enroll in STEM every year.

At the time of this study, Sandra had been teaching STEM at the middle school for twelve years. It was her first teaching position; before that, she was a mechanical engineer. Sandra studied engineering in a highly-regarded engineering college in New Jersey and years later earned her teaching credential through an alternate-route program. It was during the time she spent at home raising children that Sandra decided to change careers.

> When I interviewed for this position, I did not know what a STEM teacher was. So, I googled it to find out it was science, technology, engineering, and math.... I am guessing because I have an engineering degree and am an alternate route teacher was why they chose me.

STEM was a brand new initiative for the middle school, and Sandra was the first teacher to fulfill the STEM teacher position. When Sandra accepted the position as a novice teacher, she found that she had no curriculum and minimal supplies.

> [T]he first year, it was quite difficult because my supplies involved having only paper… because this was a woodshop, and they changed the curriculum at the end of August… I interviewed for the job the first day that the students were here.

When Sandra started teaching a few days after the school year started, she recalled being handed two-weeks' worth of design challenge lesson plans that someone had downloaded from the Internet. The substitute who had managed the class since the first day of school had already gone through most of them. "One activity was this hula hoop challenge where you got everybody in a circle, and you got to get the hula hoop to go all the way around… Basic stuff… using tin foil, making the hull of a boat in water and how many passengers could it hold…" Starting from scratch, Sandra had to teach herself everything. As a novice teacher, she developed her teaching and classroom management skills and created a new program simultaneously. Unable to find teachers to collaborate with, she searched the Internet and elsewhere looking for as much information as she could "because STEM wasn't [as much of a] buzz word back then." It seems that Sandra's identity as an engineer bolstered her confidence as she made sense of what was expected of her as a STEM teacher. In the following sections, I illustrate Sandra's self-authoring as a teacher—with an engineering background—who engages students in making.

"I Would Save Newspapers" Starting with Nothing and Building a Tech-Rich Stem Program

Sandra received no mentoring or support during her first year. It seems that her administrators completely delegated responsibility to Sandra for developing the new STEM elective. This can happen sometimes when a course or program is created as an act of top-down policy compliance. It is possible that Sandra's principal might have received external pressure to replace woodshop with STEM. For example, advocates for STEM education in New Jersey have

claimed that New Jersey was “the original Silicon Valley” and aim to reinvigorate the state’s engineering sector (Research and Development Council of New Jersey, n.d.). The New Jersey Department of Education has also identified STEM education as a priority (New Jersey Department of Education, 2020).

Sandra’s classroom was an expansive, high-ceilinged ‘shop’ space located in the basement level of the middle school (see Appendix D). The band room and the consumer science room were the only other classrooms located in the basement. Sandra’s space was equipped with high-top butcher block workstations and metal stools. Power cords hung from the ceilings on pulleys and each student workstation was equipped with vice grips. When she first arrived as the new STEM teacher, Sandra found machinery and supplies left over from the woodshop elective that she did not feel comfortable using, such as power saws and large pieces of wood. Even though she had no use for them, they remained for years. During her first year, Sandra collected newspapers at home to supplement the paper the school had given her. Twelve years later, Sandra has developed her STEM curriculum to include a considerable amount of technology. Grants from the school district’s education foundation had covered the cost of high-priced items such as 3D printers and scanners. To maintain her supply of building materials, Sandra purchased design challenge kits every year from an online STEM education retailer. “[T]hey... supply you with a kit and there's a way to build it, but I don't really have the students do that… we use the parts of the kit for them to design something of their own.”

Sandra’s curriculum for all three grade levels contained two major strands: design and problem solving. With each grade level, she spent half of each semester on robotics and the rest on design challenges, including 3D design and printing projects. The design process was the basis of every unit of study. Because she had more time with eighth grade classes, some of

Sandra's eighth grade design challenge units also focused on STEM concepts. An example is the "Metric Dragster" unit that related mass and acceleration, one of Newton's Laws of Motion. Sandra felt constrained by the academic schedule and lamented not having more time with students, especially her groups of sixth and seventh graders. "I only see those kids every other day for one marking period, so there's not a lot of stuff that I can really expose them to. Like, if we do three different things, that's it."

At the time of this study, Sandra had recently been asked to update the district-level STEM curriculum for middle school. She believed the goal was to include enough detail so that another teacher could easily follow and implement the curriculum. Sandra was apprehensive about completing the task because she felt that a detailed curriculum would undermine the open-ended nature of makerspace learning and the autonomy of the teacher:

> It's apparently been five years since the last… curriculum was written… I think they want it as if I left, someone else has to come in and be able to take that curriculum and teach… I guess just to make it easier for anybody who would be coming in. I don't know if I would agree with that 100 percent, because I find that every year you can find new and maybe better ways to have the students learn. Critical thinking, collaboration skills, because that really is kind of the focus…Because to me, having something to hand off to somebody else the way they want to do it is more like writing lesson plans…Which, you know, the next person coming in could have a different way of teaching. So, I think I kind of feel like, um, something more vague is better—the way we did it the last time. Like, okay let's focus on this strategy and how can you do it? And then we gave examples of different lessons or projects or activities that would fulfill that standard… Like… my responsibility right now is the Next Generation Science Standards, but it's the middle

> school engineering portion of that, you know, which basically is design and problem solving. So, I could really do that with lots of different activities… And for me to say, "Okay, you have to do it this way. You have to have a Maglev project," seems… I don't know. I don't know how I feel about that. I don't think it's the best way <laughs> .

Sandra's STEM curriculum, as written five years before, was very broad; simply a list of state career and technical education standards she had selected and a list of possible design projects that could enable students to meet them. With the update, Sandra was worried she would be asked to include teaching and learning procedures broken down into steps and formal assessment tools. In Sandra's view, providing detailed instructions for other teachers might give the impression that their choices were limited, and this could constrain or defeat the more open-ended approach she intended. Sandra feared that a newer teacher or a teacher new to facilitating making might lack the knowledge, confidence, or motivation to facilitate open-ended learning. Sandra also feared that by writing a detailed curriculum for the district she was potentially relinquishing control of her program and compromising some of her own autonomy as a teacher.

Self-authoring theory helps explain Sandra's desire to assert her identity as a maker and her vision for making. In addition, history-in-person theory is a way to understand Sandra's efforts to assert her autonomy and perspective, despite countervailing pressures and constraints, because it helps explain resistance to nested societal pressures. For example, Sandra's resistance to writing a detailed district-level STEM curriculum can also be viewed as resistance to the external controls that have eroded teachers' jurisdiction over their work. Teacher autonomy is a matter of contention in the enduring and farther-reaching struggle for teacher professionalism (Mehta, 2013a, 2013b).

"First, I Had to Teach Myself Everything" Self-Authoring as a Maker and a Teacher Who Engages Students in Making

In 2014, Sandra acquired three 3D printers, carts, and a digitizer scanner through a grant from the school district education foundation. The principal at the time was supportive of this endeavor and Sandra noted that there was growing support in the district back then for incorporating making activities into the middle school curriculum. Sandra believed that the arrival of the 3D printers was what really shifted her curriculum in the direction of making. 3D modeling, in Sandra's view, added opportunities for student choice and open-ended learning. The 3D printers also raised the profile of her class because few had ever seen 3D printers before. Sandra knew little about 3D printing when she wrote the grant for the printers, so she had to teach herself everything before she could teach it to the kids:

> I like to do that kind of stuff anyway so I can usually teach myself by watching a tutorial, but I've also gone to workshops put out by MakerBot and been to their headquarters in Brooklyn. Picatinny Arsenal, they came there and had like a 3-day workshop.

Over the years as she developed her curriculum, Sandra also taught herself to use various software applications. 3D printing required the addition of CAD and 3D modeling applications, such as 123D Design—part of a discontinued Autodesk suite that Sandra preferred for her middle school-aged students—TinkerCAD, Sculptris, and the robotics coding program, Lego Mindstorms EV3. With each application, Sandra argued, there was always more to learn and as a busy teacher there was only so much time to play around and explore. Sandra was candid and open with students about the limits of her knowledge. As someone who enjoyed teaching herself new things, she valued independent learning and encouraged students to continue tinkering with applications beyond what she had taught them.

> You know, I'm not an expert. I use that 123D Design, and I [say] to the students who [finish] early, "You know, why don't you look up a tool that you don't know how to use, and we'll have you teach the class and myself how to use it because I don't know how to use all the tools."

Sandra's efforts to learn how to use new tools to engage her students and redesign her STEM course to include making are further examples of self-authoring (Bakhtin & Holquist, 1981). When self-authoring, a person is motivated by her social context and her personal history (Bakhtin & Holquist, 1981; Holland et al., 2001). Sandra had begun to identify as a maker and was engaging with students as a maker might—as a collaborator—because she wanted her students to begin behaving as makers too. These are also examples of Sandra *enculturating* her students into the Maker Movement (Brown et al., 1989).

"This Should Be an Academic Course" Seeking Legitimacy and Respect as a CTE Course

Sandra's inspiration for integrating 3D printing was "Ms. Stevens," a seventh grade science teacher, now retired, who wanted to be able to print out plastic frogs—with parts inside—to accommodate students who were uncomfortable with dissecting real ones. Sandra was appreciative of the opportunity to possibly collaborate with someone, so she and Ms. Stevens wrote the education foundation grant and attended the Picatinny Arsenal workshop together. "She was printing things that she could…show the kids in her classroom and I was teaching [my] students how to design, using 3D modeling software, and then manufacture in the classroom."

Ever since Ms. Stevens retired, Sandra had tried to encourage other teachers to use the 3D printers or collaborate with her on projects, to no avail. The original reason for procuring three 3D printers was to put one of them on a cart that teachers could wheel to their classrooms. Although one or two history teachers had since asked Sandra to print replicas of historical

artifacts, Sandra indicated that no one else on the faculty had shown much interest beyond that. She believed she would be the one expected to provide any needed staff development in 3D printing, and she was more than willing to do that.

> I would like the other teachers in the building to be more involved...It's not that difficult. Even if they... wanted artifacts, I could show them how to use the [3D] printer and... make it more like a mobile... piece of equipment. I could do something like, "Maker Mondays" ... or "Tuck Tuesday" and have, after school, anyone who was interested...

That said, she worried about the learning curve involved, the logistics involved in printing student projects, and the unpredictability of 3D printers that inexperienced users might not be able to troubleshoot on their own.

Ms. Stevens was also instrumental in getting Sandra transferred to the science department. She made administrators aware that STEM was part of the science standards and continued to advocate on Sandra's behalf. Before that, Sandra was on her own, without a department, aligning her curriculum as best as she could with New Jersey Career Technical Education Standards. Sandra hoped that the science teacher title might put her STEM class in the position to one day be considered an academic class or at least be counted for Honor Roll. It seemed that Sandra's school intentionally or unintentionally awarded higher status to academic courses by making only the grades students earned in academic courses eligible for Honor Roll. Sandra wanted academic status for STEM because she believed the higher order skills her STEM curriculum emphasized made a valuable contribution to the school curriculum-at-large, filling a gap in student learning.

> [I focus on] problem solving, collaboration, [and] critical thinking, because they don't get that practice anywhere else or not a lot of it. They want to be told what to do. And I really

have seen that a lot, even recently, you know? This doesn't work…What should I do?... What do you *think* you should do?

Sandra also believed that 'raising the status' of her class from CTE to academic would attract more serious students. In her view, STEM at the middle school should be a feeder program for the high school's selective and rigorous STEM Academy. The STEM Academy offered three pathways for students: a biomedical engineering strand, an engineering and design strand, and a computer science strand. "[I]f they're in the STEM Academy, they have to be in all honors classes. Then I feel like, well, what happened in the middle school?" Sandra also believed that more serious students would be trustworthy and able to handle the varied technological and workbench tools responsibly. Based on patterns in student behavior that she had observed over the years, she suspected that some of the students who enrolled in her STEM elective each year did so mainly because the word on the street was it was a fun class that kids could socialize in while they worked. Although it was true that Sandra cultivated a relaxed atmosphere in her STEM class, she did not want students who would take advantage of that opportunity. Sandra believed that, at best, these less serious students could be unproductive and distracting, and, at worst, they could be dangerous to themselves and others when fooling around with sharp or pointed tools. Sandra foregrounded informality in her woodshop-cum-makerspace because she believed that less structure supported creative risk-taking; but she also wanted her students to feel physically and emotionally safe as they worked. In her view, not all students who enrolled in her class seemed ready to learn in a makerspace setting.

Although Sandra suspected that some students intentionally enrolled in her class to misbehave, I posit that it is also possible that some of these students were confused about what STEM was supposed to be and what was expected of them as learners. First of all, STEM is

vaguely defined as a content area (Lacy, 2016), so the course name might have been interpreted in different ways. Second, as I described earlier, Sandra's STEM class was taught in a room that was designed to be a woodshop. Brooks (2012) and Lacy (2016) suggested that room design could strongly influence student perceptions about its purpose and appropriate behavior. In addition, there is the perception that the creation of STEM courses and makerspaces in schools is "just…a way to say, 'Hey, look at what we're doing!'" (Lacy, 2016, p.78). That sentiment, communicated explicitly or implicitly, might have influenced some of Sandra's students to take the class less seriously. An example of how the grammar of schooling (Tyack & Tobin, 1994) can cause schools to categorize subjects and courses as more valued or legitimate than others, these are all possible misconceptions about the purpose and status of STEM that Sandra's administration might have inadvertently set her up to contend with.

"I Question the Students More about What They Think" Being a Facilitator

Sandra described herself as "not big into lecturing," although she indicated that she would like to introduce more content if she had more time. Sandra claimed that, instead, she expanded on what students were already learning in math and science "so they [could] use that content." Sandra believed that her teaching style was more interactive than most of her academic content area colleagues. "I think I question the students more about what they think. And…I'd like input from them."

Troubleshooting with students also gave Sandra opportunities to learn alongside them. "I've told them. I said, "Well you know that actually is helping my critical thinking skills because I'm looking at your design and trying to figure out, okay, what are we going to do to make this work because yours is different than [the group at the next table's design]." Sandra used questions and suggestions to redirect students so that they are once again actively

brainstorming and problem solving instead of freezing in a state of frustration. Her goal was to help students get their original designs to work instead of giving up and going back to square one. Sandra described how she handled it when a project was in progress and there were "a lot of students who just really didn't know what to do."

> We were having that in seventh grade a lot with the mousetrap vehicles and [at that point in the unit] we were running out of time… and so I actually showed them an example of one that I've kept. It's not the best design; it's not the worst design. This is what works with this, you know. Let's adapt these concepts for yours… Don't change yours and make it look like this, we'll make yours work.

Sandra seemed to deftly navigate the thin line between helping students 'too much' where she could take away an opportunity for critical thinking and not helping enough which could cause students to shut down.

Sandra also provided rubrics that students could use as self-assessment tools. The rubrics helped anchor students to the task at hand and motivate them to complete steps. They also served as a way for Sandra to grade student work. For example, Sandra's eighth graders could earn 50/100 points on their paper roller coaster design project by setting rolled paper columns at 90 degrees rising from the base and setting diagonal supports at 45 degrees.

"This Is Our Space" Encouraging Students to Take Ownership within Formal School Structures

Despite Sandra's concerns about student behaviors that made her uncomfortable, she insisted that making and makerspaces were needed in middle school. In Sandra's view, making was a great way for students to extend what they understood about the content they were learning in other classes. In addition, she believed it was important for students to develop

independence—and interdependence—as learners and be able to persevere through the problem solving process.

> They need to be able to be in an informal environment and be able to… Like, you're watching… a certain student fail continuously. 'It's not working! It's not working!' You know?…[Y]et, with a little advice from somebody else making it work… eventually it is successful. I think that you don't have that option in a lot of the other classes. Like, okay yeah, you didn't get the grade you wanted on a test, so you had to study, but it's completely different...[T]his is where you don't have to be the straight A student to make it work, because a lot of times it's not.

Sandra indicated that she intentionally worked to create "a more student-directed environment" where students could work with each other and try to "figure things out on their own." She wanted her students to be able to come in and get started on their own with minimal teacher direction. Sandra claimed that she actively fostered interdependence and collaborative skills among classmates and would step in to help only when she noticed frustration. As I indicated earlier, even when working with frustrated students who were looking to her for answers, Sandra encouraged a working dynamic in which she was more like a collaborator than an expert or authority figure. "We kind of work together and actually teach each other a little bit." Sandra described her makerspace as "more of a 'where we're not equals but more of a like-equals' environment. Like, this is our space."

That said, Sandra found that the nature of her classroom space and issues with student behavior made it difficult to engage students in projects that were completely student-directed and open-ended. First of all, Sandra lacked storage for the variety of materials and tools that could anticipate a wide range of projects. She also had limited space for storing ongoing projects.

Sandra had considered setting up stations where she could just leave materials and projects out on the tables but decided against it.

> I would love [stations], but I think that would also have to be a complete change in scheduling to have that. I don't feel like I would even do that with 6th and 7th grade because I see them so infrequently, but you know students that I have, maybe every day for a marking period…like the 8th graders…

Even with a change in schedule, Sandra was unsure that creating stations would be the best classroom management strategy because she anticipated student misbehavior that could cancel out the benefits. Sandra was concerned that students passing through her classroom during the day might disturb other students' projects, take materials without permission, or use materials inappropriately:

> Sandra: I don't have a lot of storage for my consumable supplies that I need in general. And…if I had everything out and displayed, I'm not sure how that would work based on the population that comes through here. Like, I make things available as they need them.
>
> Me: You find that kids would just start grabbing and playing?
>
> Sandra: Grabbing and taking. Like, I can't leave rubber bands out because they disappear and [kids are] using them for other reasons, usually. Um, I don't give out balloons. For those kinds of reasons—unless it's got a specific use. So, I never feel like I can leave that stuff out and available.

In regard to the schedule, as Sandra indicated, it created its own challenges. To begin, Sandra felt limited by the 45-minute class periods that the schedule divided the day into. 45-minute periods made it difficult for students to become immersed in their work, especially since there was time needed for students to set up their projects and materials and then put them away.

Time was needed for general room clean up as well. Sandra argued that the nature of student work in her STEM class required a longer transition period at the end of class than most other classes:

> The time flies by, but I think we have to allow like ten minutes because eight minutes isn't cutting it. Eight minutes in other classes is plenty of enough time… We don't have a lot of brooms cleaning up. You know? Sweeping and passing the broom takes a little while.

Also, as indicated earlier, the schedule made it difficult to maintain momentum from day to day or go-in depth with projects because it did not allow Sandra to meet with all of her students every day. Sandra met with eighth grade classes daily for one semester but met with her sixth and seventh graders less often.

> [W]ell, right now for sixth and seventh grades I only see those kids every other day for one marking period, so there's not a lot of stuff that I can really expose them to. Like, if we do three different things, that's it.

With no time to go in depth, the curriculum Sandra planned for sixth and seventh graders was more activity based whereas the eighth grade curriculum was more concept based:

> [My units] probably don't flow very well because I do call most of it design and problem solving. That's usually kind of what the unit is, except for eighth grade. Like mmm, like for the dragsters, that would fall within Newton's laws of motion, which would also be rockets and things like that. But I see [eighth grade] more often, so I can fit more in for that particular thing. But for sixth and seventh grade, okay like robotics is a unit, and then it's design and problem solving so we have eleven classes of robotics and eleven classes of design and problem solving because that's all I have with them.

In addition, the way Sandra's STEM class was scheduled created a situation where, starting in seventh grade, students' requisite knowledge and skills for STEM could vary widely. This was because Sandra's STEM class was an elective but scheduled so that students only attended class with students at their grade level and not with students with the same level of experience—in other words, students enrolled in 6th, 7th, and 8th grade STEM instead of STEM I, STEM II, and STEM III. Middle school students could enroll in STEM each year if they wanted, but as I mentioned earlier, there was no requirement to commit to a three-year sequence. Therefore, Sandra could have seventh or eighth graders that had never taken STEM. For this reason, when planning, Sandra had to be mindful that even some of her eighth graders might have no prior knowledge of the activities she wanted to engage them in and ready to accommodate a wide range of student ability levels.

Chapter Summary

Sandra's current role as middle school STEM teacher was her first teaching position. The year that she was hired, twelve years before I conducted this study, STEM was a brand new middle school initiative that replaced woodshop. Sandra was given the woodshop space as-is and provided only paper for materials. Sandra had a previous career in mechanical engineering and liked to learn through tutorials, so even as a novice teacher she was confident enough to develop a STEM curriculum and figure out how to use new technologies as needed. For several years, Sandra developed the STEM program with little administrative support, purchasing technological tools and materials with grant money from the district's education foundation. She had tried for years to find teachers to collaborate with and in 2014 was finally approached by a science teacher, Ms. Stevens, who wanted to use 3D printers to print model frogs for mock dissections. The two teachers worked together on a grant proposal and received the go-ahead to

order 3D printers. In Sandra's view, the integration of 3D printing into the STEM curriculum shifted the focus from design challenges to more open-ended design and making. Ms. Stevens also lobbied to have Sandra included in the science department because the Next Generation Science Standards included STEM skills. Since Ms. Stevens retired, Sandra had been unable to find new collaborators, even though she was willing to teach colleagues how to use the technology in her space and had a 3D printer on a cart that teachers could bring to their own classrooms.

Sandra believed opportunities to engage in making were important for middle school students because there were few opportunities across the middle school curriculum for students to engage in critical thinking or social learning. When given the responsibility to update the district-level middle school STEM curriculum, Sandra was very apprehensive. She feared that the goal was to create a prescribed curriculum that could be easily followed by other teachers. In her view, this could undermine the open-ended nature of making in the classroom and could constrain teacher autonomy. I interpreted this as a sign of Sandra's self-authoring as a maker and willingness to resist when she did not agree. History-in-person theory (Holland et al., 2001) recognized this type of resistance as 'engaging in contentious local practice.' It supports the contention that Sandra's actions not only helped forge Sandra's maker identity but also influenced bigger picture 'enduring struggles.' History-in-person theorized that local contentious practices and enduring struggles mutually shape each other. A possible 'enduring struggle' could be ongoing external pressure placed on the middle school by local advocates for the engineering sector or the New Jersey Department of Education to include a STEM program, and this would be nested in the even larger ongoing struggle between the field of N-12 education and outside forces trying to control it (Mehta, 2013a).

Sandra cultivated a classroom culture that was non-hierarchical, student-directed, and collaborative in nature. She wanted her class to be a space where students felt safe to take risks and fail. That said, Sandra was concerned about off-task behavior in her makerspace and suspected that it was rooted in disrespect for "this type of class," that is, a class that was informal in structure, non-academic, and did not count toward the Honor Roll. The schedule and lack of storage space also placed some constraints on how student-directed and open-ended student making could be in Sandra's class–an example of how the grammar of schooling (Tyack & Tobin, 1994) influences teacher decision-making.

Chapter 6: Eli

School Context

"Eli" was the fourth grade social studies teacher and Social Studies Coordinator at the "Lower School" campus of a large independent day school in a predominantly White upper middle-class neighborhood. The Lower School served approximately 300 students in grades Kindergarten through five. Although the local population was mostly White, less than half of the student population was White because the school intentionally selected a racially diverse student body. Eli's single-story school was built on a large, wooded property and was set back and secluded from the surrounding neighborhood. The Middle and Upper School divisions, which served grades six through twelve, shared a campus elsewhere in town. Kindergarten through third grade classes were self-contained while grades four and five used a team teaching model whereby each fourth and fifth grade teacher took responsibility for one homeroom class and one subject—either social studies, mathematics, or language arts. Science was taught by specialists assigned to specific grade levels. Fourth and fifth grade students traveled with their homeroom cohort from class to class. Homeroom class sizes were capped at sixteen. The Lower School administrative team included the Head of Lower School and the Assistant Head of Lower School. The Head of School's office was located at the Middle and Upper School campus. The Board of Trustees included twenty-one trustees, six officers, and ten honorary trustees.

Eli at Work with Students

In the following vignette, Eli meets with students in rapid succession to check in about a project. Students were lined up in front of Eli who was sitting at his corner desk, turned toward them in his rolling desk chair. Some students had project proposals in hand. Eli had provided students with a range of options for this project (see Appendix G), and some students were

waiting for Eli to approve their choices. Students could choose from a variety of creative, community, technology, inquiry, and field-based outcomes. Some students were planning to work individually; some in small groups. Many of the students who had lined up to meet with Jason seemed to be seeking some kind of direction or reassurance, and a few seemed to want help with a decision:

> Eli: <Addresses a boy> You know what; honestly, if I was you, you should just spend today playing around on [TinkerCAD]. Don't worry about the project for today. Just play with it because there's so many different things to do. And you'll probably learn so many different tools just playing around with it that you would want to start over anyways. So that's your job for today. Can you handle it?
>
> Student 1: Yas.
>
> <Addresses next student in line, a girl>
>
> Student 2: What lightbulb should I make?
>
> Eli: So, which time in history are you talking about for your innovation?
>
> Student 2: Maybe an incandescent?
>
> Eli: An incandescent from Edison? So that's cool. <Notices object in her hand.> You got that from the art room?
>
> Student 2: Yeah.
>
> Eli: All right. Well, I think you're off to a good start …
>
> Student 2: <Lingers> I don’t know if I should paint it today.
>
> Eli: You probably want to make it look as realistic as possible. Right?
>
> Student 2: Yeah.
>
> Eli: We can do paint, but let's not do that while the Chromebooks are out.

Student 2: Yeah.

Eli: Why don't you try to just gather all your materials first and kind of sketch your ideas out on scrap paper. And then we'll work on the actual putting it together.

Student 2 seemed satisfied with that answer and returned to her desk.

<Next two students, both are girls>

Eli: Have you made a Google Site before? A website?

Student 3: Yeah, we made one together.

Eli: Oh perfect…Oh, yeah the recess one?

Student 3: Oh no, the Delaware River thingy.

Eli: So, then you've made two! Yeah, I forgot that was a website at the beginning of the year. Okay, you should be good to go then.

Student 4: Oh.

Eli: Are you feeling comfortable with things?

Student 4: Yeah…

Eli offered kind guidance, but as he offered advice he continued to encourage independence. For example, when a student had a question about TinkerCAD, he directed him to play around and "figure it out." Later, Eli reminded another student that being able to figure things out himself "is a good skill to have." Based on Eli's feedback to students, engaging students in problem solving seemed to be his primary goal and I could see why. Several of his students seemed to be more adapted to receiving explicit instruction.

Eli's Background: Current Position, Education, and Early Career

Eli was one of three teachers on the fourth grade team. He taught social studies to all fourth graders. In his quasi-administrative role as Lower School Social Studies Coordinator, Eli

collaborated with social studies curriculum leaders at the Middle School and Upper School divisions to ensure a coherent vertical curriculum design. Eli had planned to be a teacher since college. Soon after graduating, he enrolled at a highly-regarded private college of education in the New York metropolitan area that markets itself as a leader in progressive education. Eli's first teaching position upon earning his master's degree in elementary education was as a founding third grade teacher at a brand new progressive independent school in Brooklyn that was adding a new grade level each year. As a founding teacher, he worked with his colleagues to create a curriculum from scratch.

> [W]e worked hard to plan that curriculum. We knew what… the overarching themes would be going into the year by… the time the first day came around, but a lot of it… I was figuring out what we were going to do on the walk home for the next day. I was changing plans as I walked in the next morning because it was… so fluid...

The school had purchased an old church as its facility, so the classrooms were unconventional in size and shape. "My classroom was at least 40% bigger than this...[W]e had...a whole block area in third grade which is unheard of." Eli believed the two years he spent teaching and developing curriculum at the school in Brooklyn were formative and made him much more confident at being able to "hack things together and plan effective lessons."

However, since Eli left his Brooklyn teaching position, he had changed the way that he interacted with students. As a novice teacher at the Brooklyn school, Eli's third grade students would get excited over his playful antics and compliment him for being fun. The students' frequent references to him as 'the fun teacher' made Eli think his teaching skills must not be the thing that stood out the most about him. At the time of our interview, Eli had been teaching

elementary school for seven years. He described himself to me as “not quite as fun” as he was when he was younger, but a better teacher. I asked what he meant by that:

> When I was.. In my first couple of years, I was, like, kind of.. running around with the kids at recess and, like, I knew all the same music and everything. But I'm a dad now. Like I'm, you know, in a different point in my life. So, I think before they saw me as.. that young kid, like when kids see a babysitter as a high schooler—like, all about it. So, I'm more of, like, a teacher age now; I'm not the young teacher. But I think my style has stayed the same. It's just I'm learning... better tools and techniques and really the making space, again, just kind of pushes me to do more and more because I see the success of it.

This process of deciding how he was going to position himself in relation to students, I posit, is an example of Eli’s self-authoring as a teacher. In the following sections, I provide more examples of Eli’s self-authoring as a teacher and a maker in relation to his school context.

“I Think Tradition Is a Hard Thing to Get Over” How School Structures and Norms Influence Teacher Decision-Making

As I described, Eli’s first teaching experience was in a new progressive independent school. As a founding third grade teacher, he helped shape the nascent culture and curriculum. Eli’s current school was quite different: with a 150-year history there had been plenty of time for traditions and attitudes to become fixtures within the school culture. Eli patiently described his school context as making attempts to transform in such a way that it could support more creative activity. The school was known, compared with other large independent schools in Northern New Jersey, to be more traditional in its approach to schooling, and part of this traditional leaning was an emphasis on core academics. Eli maintained that the schedule, the classroom

spaces, the grading policies, the school calendar, and the planned curriculum made it difficult to take a student-centered, open-ended approach.

> [T]hey're encouraging more and more for teachers to have hands-on activities and creative spaces, but the school structure isn't set up for that right now. So, I kind of take some freedom there sometimes.

From his perspective as a progressive educator, Eli could see the difference in mindset at his current school. He found himself evaluating policies and traditions and deciding for himself which of these he would adopt and which he would reject. For example, when Eli was a new teacher at the school, he carefully examined the Lower School tradition of teachers making students wait outside the classroom door in the morning until the teachers were ready to invite them in. Before long, he decided to drop the tradition because he believed that it subjugated students instead of making them feel that the classroom was their space. As a progressive teacher, he surmised that this subjugation of students was a component of authoritative traditional schooling (see Smagorinsky, 2010):

> [I]f they show up to a class and the teacher isn’t there… they're not allowed in. And I totally get that, but that's not something I wanted to do with my students. It's not the feeling I wanted. So, every morning I put up the morning message and I make it clear to them during the first week of school, if I'm talking to a teacher next door or getting a cup of tea, that's fine, you can come in and follow directions. Like, if they're, if things come up and we can't follow our class goals and guidelines then we'll deal with that, but this is your space as much as it is mine as long as you treat it respectfully.

Eli also disliked giving grades for making projects. His workaround strategy was to put good grades on report cards and then use the written comment section or parent conferences to provide constructive feedback:

> [Grading is] a challenge for me…I think I'm… pretty comfortable with writing a narrative report but not necessarily assigning a letter grade to this one kid's creativity…and… thinking outside the box. I'm not of the mindset [that] I'm really… testing to see where that kid ended up and where they needed work… I'd rather address that through parent-teacher conferences and comments, so I think if I can help a kid out because they're coming to me, they're asking good questions, they're receptive to feedback, I'm happy to have their grade reflect those positive aspects of it as well, not just.. what they could do independently.

As evidence of learning, Eli designed rubrics for student making projects that provided his fourth graders with easily achievable ways to earn points (See Appendix F). For example, Eli's fourth graders could earn 30/100 points by writing a statement that clearly demonstrated understanding of the targeted social studies content, and students could earn most of the remaining 70 points in ten-point increments by putting care and effort into the project presentation, proofreading, completing the project on time, and doing a thorough reflection on their process.

Eli was hopeful that the school, as a whole, was indeed slowly changing and reaching toward a less traditional model. However, in the Lower School, he could see where there was resistance to change and, in his view, it seemed that much of this resistance was caused by a lack of reflection at the administrative level.

> It's still a challenge when we go out into the woods, which is something we still do. I would say there are still…people who are worried that a kid's going to get poked in the

> eye. And that may happen… [T]o a certain extent, school is part of the world and there's risks… I mean, they're at recess every day playing football, so I don't think our risks are any higher than the other risks they're taking.

In the meantime, Eli seemed to share a similar progressive ideology with a few of his colleagues, including the science and art teachers. Due in part to the tight-knit, collegial nature of the faculty, and also the way the small building was organized spatially, it appeared that there were opportunities for teachers to influence each other through daily interactions. The science and art teachers had taken the lead with 3D printing, tinkering, and robotics, and Eli seemed to be a recognized leader among classroom teachers with his interdisciplinary projects—in fact, several had approached him "for input on lessons." He hoped to include more making in his curriculum as time went on.

> I would love to see it work. I'm trying to bring more and more of it into my classroom, but there are limitations on that for scheduling all of the materials and… what people or how far people are willing to go with me on that. So… I don't know yet what a [proper school] makerspace looks like, so right now I'm just trying to make my classroom as much of a makerspace as possible… whenever I can.

In keeping with grammar of schooling theory (Tyack & Tobin, 1994), Eli argued that the traditions of schooling, in general, make it difficult for teachers and schools to create successful school makerspaces. After visiting other schools to see their makerspaces, he concluded that, given the open-ended nature of making, not enough time was being given to it. "I have been in a couple of schools now, and it seems like everybody is always trying to create a makerspace, but no one has one that's functioning." He saw one makerspace he liked, but it was in a teacher's classroom and not a space that could be accessed by all students. Eli's determination was that

teachers in these other schools faced the same structural issues he faced: constraints caused by traditional academic scheduling, access to resources, and availability of appropriate spaces. He imagined that many schools face the same challenges. “I think a lot of schools are trying to create a makerspace that’s kind of, like, in this gray area and I haven't seen that work yet.”

Eli’s classroom was smaller than the average public school elementary classroom, but he did what he could to make it work:

> I just find the more space in my room the better. So, when we got this new classroom a couple years ago we were given tons of furniture. I think we had two more of those big [closets] in here and then two metal filing cabinets and maybe one more thing, and I've since then just got rid of them. And if you notice, like, the shelves, like, all the bottom shelves are basically empty because those are spaces for projects… So, I definitely enter the year with an empty shelf for each homeroom that I have. I have four of them. I have four classes coming through. I try to be as minimal as possible. Um, without being like <laughs> Spartan.

Despite challenging constraints, Eli was still interested in increasing the amount of making his fourth grade students were doing and constantly looked for meaningful entry points. This was because he recognized a connection between making and the way he believed learning actually happened in the world outside school:

> I think I'm very much part of the system that has taught kids that they come to school, they bring their backpack, go to their locker, sit down in this class, sit down in that class, the bell rings, go to lunch…That, ideally, is not what our education system is built for. It should be preparation for the real world.

Over the years, Eli had integrated making into many of his social studies units and felt he had the autonomy to do so without any kind of professional risk as long as his students continued to meet the standards he and the other social studies curriculum leaders at the school had set in place for social studies learning. Eli seemed to value crafting curriculum, and even though his independent school did not require teachers to formally codify curriculum; for example, Lower School administrators never asked teachers to submit lesson plans for review, Eli preferred writing his grade-level curriculum out:

> So, fourth grade is designed as New Jersey history right now, we may be changing that in the near future, but right now…And I have an outline for the year, so I have a document for each major unit and it's like maybe three to six weeks and I have…the week and each day and maybe five or six words to express to describe to myself what the main topics are that day and activity, like a big activity and then…what the homework assignment will be. They're also subject to change for whatever reason, but that outline allows me to have an idea of what I'm going to cover, um, you know, assembly days, days where I might not have something or have the time, where I'm going to break for winter break, spring break, and make sure I'm going to get to everything and can like, budget [time] for projects and everything else and there are also times where I'm realizing like, oh I have four extra days…let's tack on a project there or make this project more extensive. Then when I get to each unit and each day, specifically, I have...a little folder. Not a folder, like a binder sheet, and in there I have all the papers that I would need to copy or access and then I have like a big post-it with kind of like notes for myself about main points to hit. …I feel fine changing them as I go around and especially, like, from class to class because not every section is the same; but those are like the things I need to hit to make sure I'm on

> track with all four of my classes... things are consistent with them getting the skills and the content that I want them to have.

When designing a new unit of study, Eli usually started by creating a detailed rubric, like the one I mentioned earlier (see Appendix F). The rubrics he created for making projects provided students with various choices of some kind, such as, in some instances, a choice of what kind of product they could make (Appendix G). “I try to leave everything as open ended as possible, while still having a clear framework and set of expectations.”

“I Feel Supported” Staying within One’s Zone of Control to Avoid Criticism

Despite being a teacher with a more progressive philosophy working within the more formal curricular constraints of a more traditional school, Eli felt supported by his school context as he strived to include making in his curriculum. This support came partly in the form of collaborative opportunities with colleagues, including the third and fourth grade science teacher:

> We are really working on some different interdisciplinary lessons and units between me and science. We see a lot of overlap there and we're trying to make it more combined in the future. Around, I mean, a big one is the Industrial Revolution, which we’ll probably do in early March. So, finding new ways to tie that in.

Eli also partnered with the fourth grade language arts teacher:

> We do a persuasive writing letter as part of our New Netherland unit where they write a petition to Governor Peter Stuyvesant about if he should fight the English or surrender to the English in 1664. So, Mrs._____ teaches language arts. We work on that together...

Support also came in the availability of materials and tools, such as 3D printers and Chromebooks for students, and “a lot of freedom” over his curriculum and teaching. Eli

described parents and students as supportive as well. “I am hearing from parents every year that their child really enjoys doing these activities and projects and that it kind of makes social studies come alive for them.”

However, although it appeared that Eli’s Lower School administration was supportive of making on the surface—for example, they had provided the garden plot that Eli chose to use for the fourth grade Lenape study, funded professional development opportunities, and facilitated the collecting and storing of reusable materials, such as plastic bottle caps—they had not gone to the point where changes in policy or their own attitudes toward making could facilitate Eli and other teachers’ making work with students in more substantive ways. For example, Eli described feeling discouraged from using chisels and woodworking tools to build model dugout canoes with students:

> I could definitely tell, as the project went on, the administration was worried. And I had taken all the necessary safety precautions. I'd done it before at my old school, so I wasn't worried, and as… a 25 year-old it felt like no big deal, but now I'm not sure I want to put myself through that, really, like having people anxiously peering into my classroom.

In fact, it was the third and fourth grade science teacher who had spearheaded the purchase of 3D printers for the Lower School with support from the Director of Technology and funds taken from the K-12 technology budget. Making at the Lower School, in all forms, had emerged from the teacher level without any direct involvement from the Lower School administration.

“Getting Kids’ Hands Dirty” Finding Space in the Social Studies Curriculum for Hands-On Problem-Solving

At the time of this study, Eli had been teaching at his current school for five years. This more traditional independent school seemed to value teacher autonomy more than any unifying

philosophy of teaching, and one result was a wide range of teaching approaches from the more traditional and teacher-centered to the more progressive and student-centered (see Smagorinsky, 2010). Based on what I observed, Eli's instructional style seemed to be more student-centered, but his implementation of curriculum seemed to be more teacher centered. In other words, he seemed to be committed to delivering the planned social studies curriculum that he had developed, but within the existing curriculum he provided students with opportunities for creative choices and open-ended work. I could see that he made himself available to confer with students individually and was generous with constructive feedback and assistance. Eli claimed that his main focus as a teacher was creating experiences for students that he believed they would love and think of as fun:

> [A]s I…experimented with things and went through my classes I realized…that being able to create is a large part of that… and... I think the more I saw it, creation—in a variety of ways—was really pedagogically sound and rewarding for students and it resulted in a deeper understanding… [S]o, I think more and more my focus turns not only from, like, engaging experiences but to… things that students can get their hands dirty with and really create on their own… I'm still very much in the process of learning how to do that effectively and finding more opportunities for it in the curriculum.

Eli included many hands-on projects in his social studies curriculum. As a way of evaluating his own teaching, he gathered student feedback and monitored responses to the projects he designed. Over time, he had learned that projects that he might think of as 'fails' might still be very popular with the students, and this has modified how he assesses his teaching. "I think…first and foremost there's an excitement about learning social studies, which I think is successful."

Eli also indicated that going through the process of creating and innovating when planning curriculum had pushed him to become a better teacher. One project that Eli described as "something that kind of worked, kind of didn't"—and helped him grow as a teacher—was a stop motion animation project that he implemented for two years. He enlisted the technology specialist in his building to help him plan it, and this involved first experimenting with stop motion animation and then making a short video. After that, Eli and his colleague guided the students through the filmmaking process so they could make their own stop animation videos about European explorers.

> [I]t was incredibly difficult because we were using modeling clay and it was hard to make it look great and the editing was really labor intensive. [T]he finished product that came out looked kind of sloppy for a lot of kids, so we did it for two years and then decided to move elsewhere with it. But…even though the product looked sloppy and not what we were looking for, I think the process was still really valuable.

'Sloppy' student products could be misconstrued by tuition-paying parents, or prospective parents touring the campus with admissions staff, as a reflection of low expectations or poor supervision. Parents might also feel concerned if their child's work appeared to reflect a lower level of achievement than other students. Therefore, Eli considered it to be in his own best interest to present finished student work that looked neat and carefully completed. "There is definitely some unspoken/implied pressure from admin and parents to make things look good, and so projects that don't look good can be an issue. That's probably the largest issue." Despite having to be somewhat conscious of students producing quality work, Eli valued problem-solving as a core aspect of making:

> [The most common problem solving challenge that comes up] is if something doesn't go according to plan, how do we deal with that itself? Like don't, let's not get ahead of ourselves and worry or abandon it. If something doesn't happen, how do we actually assess that it's not working, our Plan A is not working, to the point where we need to come up with a Plan B and then let's go about that. I think that's probably the one that I encounter the most often, and I most frequently see kids really discouraged by their Plan A not working, and people talk about having a Plan B, but I think the biggest thing for me is right, well let's figure out why Plan A isn't working…

Eli explained that he wanted problem solving in every project and across the entire fourth grade social studies curriculum.

The inclusion of making and iterative problem solving in the social studies curriculum seemed to be limited to Eli's fourth grade classes. Eli was the only teacher of social studies in the building who was actively trying to implement making and therefore was the sole idea generator for his academic discipline. Even within the Maker Movement literature, there was little mention of social studies teachers self-authoring as makers. Therefore, Eli had to figure out how to include more making in social studies by himself.

"I Don't Personally Really Think of Myself as a Making Teacher" How Different Teachers' Conceptualizations of Making Influence Teacher Identity

Interestingly, although Eli tried to design and implement as many hands-on making projects as possible, he did not identify as a teacher of making:

> I don't personally really think of myself as a making teacher. Um, I think the art teachers here do a tremendous amount, and they're... both really talented, and I think that's a really strong part of the school curriculum. Um, we are lucky to be in our situation, we have a

> lot of arts built into our program. So, any additional things I can bring into my classroom, I see as a bonus.

As I mentioned earlier, the science and art teachers had introduced 3D printing, robotics, and tinkering into the Lower School curriculum and frequently engaged students in tech-based making. Eli seemed to reserve the maker identity for them. After all, in his view, he was mainly responsible for delivering social studies content:

> As far as classroom teachers go...there is probably a perception that there's a lot of making going on here and we're doing some. I would like to be doing more…. There are… certain benchmarks that I need to get to in… Skills that aren't all… Well, none of those benchmarks require making. I'm putting [making] into my curriculum because I value it, and I can get to those other places with making or with making on the side sometimes.

Eli implemented making in his own low-tech way, which seemed to complement the social studies curriculum and was different from what the science and art teachers were implementing and promoting as making to the rest of the faculty. The science and art teachers' consensus and influence on what constituted making at the Lower School seemed to make Eli doubt whether what he was doing was actually making. Therefore, Eli seemed to confine his self-authoring as a maker to his immediate domain—that of classroom teachers. It seemed that he was a social studies teacher first and his identity as a maker was secondary—or perhaps less developed. It appeared that Eli was ready to contend with local conventions regarding teaching and learning in general, but he was not ready to publicly challenge the science and art teachers' narrower, tech-based definition of making.

"It's about Making Meaning" Making Can Be Both Physical and Mental

In the privacy of his classroom, however, Eli described making in two ways: the physical and the mental. Although he valued the hands-on building aspect of making, what he valued most was making meaning. To Eli, it seemed one type of making meaning was the act of interpreting. For example, in Eli's view, students can make meaning by writing, such as preparing notes for a debate, which involves synthesizing content and ideas. "I think it's impossible to write something without making meaning." Eli indicated that he often used making as a way for students to demonstrate understanding of class content.

> I think when I can present… information about a time and place in history… and then give the students an assignment like… write a petition about fight or surrender… I want them to use everything to make an art piece like that— a written art piece—that really shows a full comprehension of what they've been learning and an ability to apply it.

Another way that Eli believes students can make meaning is by engaging in a useful project; for example, designing and planting a class garden. He described how, when the school administration granted him the small plot outside the school building to plant a garden, he and all of his fourth grade social studies students spent three and a half weeks measuring and designing a garden that supported the fourth grade study of the Lenape. When the design was complete, Eli collaborated with his students to write a budget proposal that they presented first to the administration and then to the whole school. Once Eli and his students got the funding that they needed, they were able to plant the garden.

> [I]f I think about [making] in terms of creation, [our Lenape Garden] is probably the highlight. But a lot of smaller stuff I do, like just getting the kids involved, and even if

> they're not necessarily making something new with their hands...they're…making new meaning.

Eli seemed to make the most of any opportunity to engage students in making, and he also appeared to be adept at recognizing opportunities that would work within the constraints of school structures, including the classroom space, schedule, and curriculum. It is even possible that Eli's conceptualization of making was partly shaped by these constraints.

"It's Not Just the Physical Space but the Emotional Space" How Building a Sense of Community Facilitates Making and Makerspace Management

As indicated earlier, to facilitate student making, Eli cultivated a classroom space that fostered student independence, belonging, and ownership. To support independent learning and student use of the classroom space as a tool, Eli kept furniture to a minimum and organized desks so that students had ample space to move around. With four classes coming and going over the course of the day, he found that it worked better for him to be a minimalist. Eli's classroom was smaller than an average elementary school classroom, but the fourth and fifth grade wing in Eli's building included a large, bright, naturally lit open space, known as "the commons," that was carpeted and furnished with sofas and a few small square tables with chairs. Teachers were encouraged to use the commons and the hallway as extensions of their classrooms. Eli's classroom was directly across the hall from the commons, so it was easy for him to use it as a breakout space where students could meet in small groups and still keep an eye on them. Therefore, although Eli's classroom might have seemed small for a makerspace, he was able to 'extend its walls' by making use of other adjacent space options. To facilitate supervision when students were working in breakout groups, Eli fostered trustworthy behavior by engendering a sense of ownership for the spaces where the students worked, especially the classroom. He

wanted students to feel that the classroom was as much their space as his. One way Eli cultivated student ownership was by only hanging posters or decorations on the walls that were directly related to the current curriculum unit. He kept his personal items limited to the area around his small corner desk. As discussed earlier, Eli also allowed students to enter the classroom when he was not there.

> I make it clear to them during the first week of school...this is your space as much as it is mine as long as you treat it respectfully...and…I think that message gets across, like they feel ownership in it, and I think it makes for...a space where they're comfortable taking ownership of their things and... creating within it.

Therefore, to Eli, developing student responsibility, and their identities as makers, is as much about giving up control as it is setting expectations and treating students as collaborators.

Another way that Eli sought to build community around making was by finding authentic audiences for his students' projects. The Maker Movement encouraged networking, collaborating, and open-sourcing facilitated by the Internet and social media, but school safety policies limited Eli's freedom to facilitate student relationships with adult makers outside school. Eli wanted an audience who could validate his students' hard work and also potentially help students develop their ideas and provide access to other makers. To work around this constraint, Eli was interested in one day finding a school-approved partner organization that might cooperate in creating a safe environment for his students to interact with society. In the meantime, he relied on support from students' family members and neighbors:

> The most important next step for me is an authentic audience. I'm really working hard on that. I have some making projects that have it. Some that are kind of in between where I want it; some that I'm working on trying to figure out the best way to do that. But I think

> outreach into the community and having an authentic audience as a result of that can really magnify so much of what they're working on.

I asked Eli if he could paint a picture of what an authentic audience could be and how his projects would fit:

> So, this one's a simple one. I think it's a step that we're going to try to take this year as much as possible, like, their final project where they interview someone who lived in New Jersey and then have a huge variety of options for what type of project they make about that person to represent part of their life. Last year we had them share with students and adults for, like, a museum day. I would love to be able to have those people that they interviewed come in. So, we'd need advance notice and permission from everyone and a bit more planning time, but that's something that I don't think would be impossible to do… It would just require some organization and I think it would really step up the accountability for the students because they would understand what the purpose is…

Eli also indicated that one day he would like to take students out into the community to work on projects as well.

Chapter Summary

Eli's teacher preparation and first teaching experience took place in progressive educational settings. As a founding third grade teacher at a new progressive independent school in Brooklyn, Eli had helped shape the original school curriculum and culture. Eli described the curriculum development process there as collaborative and "fluid," and he learned to quickly "hack things together" to plan effective lessons. Eli's current school, on the other hand, was 150 years old, more traditional, and more rigidly structured. However, Eli retained strong democratic principles that continued to inform his teaching practice. For example, he cultivated a

collaborative learning culture among his fourth graders and fostered a sense of ownership and community in the classroom. As the Lower School Social Studies Coordinator and a social studies teacher, Eli seemed to identify more closely with the social studies curriculum than with making. However, it seemed that this perspective might have been fed by doubts over whether what he was doing with his students really counted as making. The Lower School science and art specialists had promoted their own tech-based conceptualization of making throughout the building and Eli did not seem willing to openly contend with that view. Privately, Eli defined making as both physical and mental, and although he appreciated the hands-on building aspect of making, he foregrounded making meaning. He believed that students could make new meaning out of experiences even if they did not create some new 'thing' with their hands. In Eli's view, important ways to make meaning in social studies were through interpretation and writing. Eli's interest in developing interdisciplinary units of study seemed to create collaborative opportunities with other teachers. It was through his collaborative relationships with colleagues that he felt most supported in his attempts to engage students in making. Eli described his administrators as appearing to be supportive of him engaging students in making but in practice being risk-averse and concerned about students injuring themselves with sharp tools.

Chapter 7: Cross-Case Findings

Tensions Between Competing Fidelities to N-12 Curriculum and Teaching Practices and Maker Movement Practices Led to Discomfort and Compromises

Mary, Sandra, and Eli shared a number of teaching practices in common, as Discourse theory (Gee, 2014) would predict. Some of these practices seemed to be at odds with making practices, as I describe in this section. For example, all three teachers shared the view that it was normal, and good teaching practice, to begin planning a curriculum unit with the desired outcomes in mind and also normal to design and schedule student learning experiences so that students might develop sets of skills and understandings over a given amount of time. When interviewed, Mary, Sandra, and Eli made indirect references to the "Backward Design" framework (Wiggins & McTighe, 2005), which seems to have become a convention in New Jersey for planning units of study. In the three schools I visited, there was a formal curriculum in place for most content areas. The two public schools used state standards to inform vertical curriculum alignment. The independent school did not invoke state or national standards publicly, but as grammar of schooling theory (Tyack & Tobin, 1994) would predict, it used standards as a resource to ensure its curriculum remained competitive with public schools. Assessment was another shared practice. As N-12 teachers, Mary, Sandra, and Eli seemed to work under the assumption that "good" teachers regularly assessed their students and used the student data for various purposes such as addressing individual student needs, making adjustments to curriculum and teaching, and periodically reporting on student progress. In their view, student assessment also held teachers accountable, whether or not they shared the data with supervisors, and it empowered teachers to reflect on their own teaching practices. With that being said, the three teachers felt uncomfortable assessing their students' making.

Discourse theory (Gee, 2014) contends that some of the norms and beliefs that the three teachers shared might be influenced by *folk theories* about what is effective teaching practice. Gee's (2014) Discourse theory defines folk theories as statements, beliefs, or practices that are based on uninformed speculation, untested anecdotal evidence, unexamined beliefs, or partly understood scientific theories and passed around among members of a Discourse. Some folk theories might even influence, or be represented as, scientific theories:

> We all acquire folk theories and are apt to go on using them except when we get far enough into some endeavor that we need specialized knowledge. Folk theories, thus conceived, are not necessarily rigid things, insensitive to evidence and closed to novelty. They change as new facts and ideas are absorbed into popular culture (Bereiter, 2002, p.7).

In any respect, folk theories are commonly used within a Discourse to rationalize practice. They also serve as part of the Discourse's unifying belief system that influences social practice. If Discourse members' folk theories and practices deviate too far from those of other Discourse members, the Discourse will either attempt to pull them back in line or cease to recognize them as members (Gee, 2014). All things considered, it seems possible that the prospect of assessing students' making challenged Mary, Sandra, and Eli's folk theories about assessment.

One folk theory of assessment that is perhaps implicated here "treats learning as the accumulation of items of mental content" (Bereiter, 2002, p. 9)—a commonly held perspective on assessment that originated in behaviorist practice. This folk theory of assessment leans upon the folk theory that the mind is a container. It is likely with this view in mind that, although Mary, Sandra, and Eli believed that assessment had its place as a useful teaching practice, none of them thought it was appropriate to assess their students' making projects. Yet, *not* assessing

did not seem like an option. In response, the three teachers questioned and modified their assessment practices to satisfy their points of view as makers. For example, instead of assessing the outcome, or product, Sandra focused on student participation in the learning or design process:

> [I]t's not assessed on the vehicle or the performance of the vehicle, it's assessed on, okay, building, if they're...doing building, great. You know... just the fact of doing it (Sandra).

Mary based students' grades mainly on attitude, giving students credit for demonstrating high levels of interest, motivation, and signs that they were developing self-efficacy:

> I take a lot in with student engagement and what they're doing and then assessing are the kids working? Are they behaving? Are they engaged? Are they asking me questions? And then I throw the grades on the report card from the top of my head (Mary).

Eli's workaround strategy was to put good grades on report cards and then use the written comment section or parent conferences to provide constructive feedback.

> I think if I can help a kid out because they're coming to me, they're asking good questions, they're receptive to feedback, I'm happy to have their grade reflect those positive aspects of it as well, not just.. what they could do independently (Eli).

In addition, Eli and Sandra routinely created detailed rubrics that they used to scaffold student success. The rubrics, intended to be used by students for self-assessment, provided students with opportunities to earn points in various concrete and easily achievable ways.

Mary, Sandra, and Eli's attitudes toward assessing student making seemed to imply that the traditional goals of assessment, or the goals of traditional assessment practices, were

incompatible with the goals of making, which were, perhaps, unmeasurable—so, they performed assessment merely to satisfy the norms of the teaching Discourse. All three teachers managed to subvert the assessment requirement by choosing learning indicators that were easy for students to demonstrate and could satisfy the teaching Discourse without reneging on their commitments to the making Discourse.

In addition to the pressure to assess, instructional approach was another area of tension between the teaching and making Discourses that Mary, Sandra, and Eli experienced. All three teachers indicated that their philosophy of teaching was student centered, which is what the Maker Movement literature has argued would be most conducive to making. However, when I visited their classrooms, I noted that each teacher used a blend of teacher and student-centered practices. It is not unusual or wrong for a teacher to identify as student centered and actually practice along a continuum between teacher-centered and student-centered (Garrett, 2008). Nevertheless, in an ideal makerspace setting—as the Maker Movement literature claimed—projects would originate in the students' imaginations and develop at their own pace, and students would learn skills and acquire materials as needed and on the go (Dougherty & Conrad, 2016). Alas, Mary, Sandra, and Eli felt pressure from the norms of the teaching Discourse to design and plan student learning experiences in advance, as Mary indicated:

> [B]ecause what I do is so open ended, and my philosophy is so open ended, I have a very hard time… formalizing it as a curriculum in terms of assessments and lesson plans and... time... (Mary).

Conceivably, makerspace learning in its ideal form would be hard for a teacher to accommodate because student interests and ideas could lead in endless directions, especially if different student ideas began to feed on each other (although this, it could be argued, is the goal (Bereiter, 2002)).

Any attempt to plan for ‘real’ making in a school makerspace setting would have to anticipate spontaneity and student ownership, both of which are difficult to support in the highly structured grammar of schooling. Feeling unable to support ‘real’ making within the constraints of the teaching Discourse, the three teachers instead found ways to compromise so that they could work within teaching norms to engage students in ‘some form’ of making. However, having to frequently compromise their values as makers to conform more closely with teaching norms or take professional risks to conform more closely with maker norms left the teachers feeling uneasy. As I mentioned in Chapter 4, Sandra was feeling apprehensive about being tasked by the school district with writing a detailed district-level curriculum for her STEM class:

> It’s apparently been five years since the last.. curriculum was written… I think they want it as if I left, someone else has to come in and be able to take that curriculum and teach…(Sandra).

In Sandra’s view, providing detailed instructions for other teachers to follow could constrain or defeat the more open-ended approach she intended.

Mary struggled with ambivalence toward district-level curriculum. With nearly 25 years of teaching experience and complete autonomy over her current technology program, she was in the habit of planning for teaching quickly and informally, remixing ideas, hoping to target student needs and interests that were specific to the group at hand:

> I came up with this like…like I'm serious like it was probably the afternoon before you came in. It was like, I’ve got to do something with these kids, like, they're losing it with this coding (Mary).

Mary found it difficult to create a pre-planned curriculum because even between two classes at the same grade level she experienced a great deal of variation. That being said, despite her own

contention that her informal, differentiated, and social approach to teaching and learning really seemed to work for her students, having to "make things up" all the time left her feeling burned out and struggling with feelings of self-doubt. As much as she valued her professional autonomy, she also worried about whether or not she was preparing her students adequately for the kind of making the high school was doing. Mary's fear was rooted in the fact that neither Mary's K-8 district, nor the regional high school district had imposed a district-level curriculum for technology.

Mary knew that teachers in other K-8 feeder district schools had also begun incorporating making in different ways, such as tinkering in the library or robotics in technology class, but in the absence of a district-level curriculum or regional district-level curriculum for making there were also no school-based collaborative efforts or attempts at coordination among the K-8 district schools for implementing making. Mary's anxiety about this stood in striking contrast to the confidence she demonstrated while working with her students in the classroom:

> While I said that I don't think just anyone can come in here and do this, sometimes I think someone can come in here and do this a hell of a lot better than me. And that's probably what it is. Someone who has more robotics experience, more coding experience than I do. I mean, I don't have a background in this stuff…(Mary).

Although Mary was confident in her knowledge and skills as a teacher and also confident in her understanding of how to facilitate making with students, it seems that working in isolation without the support of a community of teachers who were also straddling the Discourses of teaching and making left Mary vulnerable to these occasional pangs of inadequacy. That being the case, Mary's impulses were to conform more closely to N-12 practices or stay hidden, and she found herself fluctuating between the two choices.

Eli's similar feelings of tension between the teaching and making Discourses were related more so to his concerns about his identities as teacher and curriculum leader. As a teacher, he wanted to be taken seriously by his colleagues, his students, and the parents, so he worked hard to be a 'good' teacher. This mindset dated back to Eli's days as a novice teacher at his first school in Brooklyn when his third grade students would get excited over his playful antics and compliment him for being fun. The students frequently referred to him as 'the fun teacher:'

> But I'm a dad now. Like I'm, you know, in a different point in my life. So, I think before they saw me as… that young kid, like when kids see a babysitter as a high schooler, like, all about it. So, I'm more of, like, a teacher age now; I'm not the young teacher (Eli.)

It appeared that Eli feared losing the respect of others around him at school if he placed too much emphasis on fun and did not position himself as an authority figure. In addition, as the Lower School Social Studies Coordinator, he felt responsible for the integrity of the Lower School social studies curriculum. Despite wanting to protect his image as a 'good' teacher and the social studies curriculum, Eli was still interested in increasing the amount of making that his fourth grade students were doing and constantly looked for meaningful entry points. This was because he recognized a connection between making and the way he believed learning actually happened in the world outside school.

Eli insisted that the main goal of each making project was to help students "make meaning" of social studies content, not the creation of a product. Although Eli was a strong proponent of hands-on learning, as a content specialist he viewed making as something extra that he opted to include as a means for students to apply their content learning and not as the core curriculum. It seemed as though Eli was not committed to self-authoring as a maker and might have been more comfortable with just dabbling in making and the idea of being marginalized

within that Discourse than being marginalized within the teaching Discourse. However, as I mentioned in Chapter 6, Eli indicated that he did not identify as a maker partly because his conceptualization of making was different from what the science and art teachers were doing and what their consensus on making seemed to be. Eli's identification as a maker also seemed influenced by his sense of obligation to the planned social studies curriculum and having not yet figured out how to integrate making in quite the way he wanted. Therefore, it is possible that Eli already viewed himself as marginalized within the making Discourse and thought the best he could achieve was a "quasi-maker" identity.

Formal School Structures and Routines Hindered Fidelity to Maker Movement Practices

Aspects of traditional N-12 school design in Mary, Sandra, and Eli's schools also appeared to be incompatible with Maker Movement norms and this created additional tensions for the teachers. Formal structures and routines, such as the school calendar, academic schedule, classroom design, and school supplies procurement highlighted differences in the expected nature of activities in N-12 schools and makerspaces. Mary, Sandra, and Eli indicated that these particular structures thwarted spontaneous, divergent, and open-ended student work. Because the teachers perceived these formal school structures as fixed and beyond their control, they were forced to adapt their practices to conform with these constraints. For example, the school calendar, adopted annually by the school board, divided the school year into marking periods. This practice assumed a linear view of learning and supported the traditional teaching practices of imposing deadlines and emphasizing results. As another example, the academic schedule determined how often the teachers could meet with each of their classes, the length of each class session, and class size. Further, the teachers' classrooms, when used as makerspaces, were not designed for multiple groups of students working on ongoing interdisciplinary projects with

open-ended materials. Although Sandra's classroom, a former woodshop, provided plenty of room for students to work on building projects, it lacked the capacity to store the range of materials she wanted to have on hand and students' in-progress work. Having to order supplies in advance was another constraint that limited the teachers' ability to provide for spontaneous student-led projects. School purchasing and procurement policies required that teachers submit one supply order per year in advance of the school year. Taken together, the school calendar, academic schedule, classroom space, and supply procurement routines seemed to form the absolute parameters, or the grammar of schooling (Tyack & Tobin, 1994), within which the three teachers could opt to align their practice as closely with the making Discourse. There is reason to believe, therefore, that despite the three teachers' seemingly reasonable attempts to innovate by adopting making practices, they would continue to contend with invisible opposing forces that resisted their innovations. In the remainder of this section, I draw on my data to more clearly illustrate how school structures seemed to hinder the three teachers' making practices.

In the context of the academic schedule, class sessions at Mary, Sandra, and Eli's schools were 45 minutes long, and this included time set aside for set up and clean up. Mary foregrounded student engagement and regretted ever having to end class when students were still so deeply involved in their work. "When it's three o'clock in here and the kids don't want to leave, I mean, that says a lot" (Mary). That being said, Mary found it valuable and necessary to include routines at the start and end of each class for the sake of social-emotional learning and supply management. First, she provided several minutes at the start of each class for students to center themselves:

> I like them to come in and sit.. and sometimes I even turn the lights off and give them a few minutes to get their head on straight before we get started.. (Mary).

Mary also set aside several minutes at the end of class for a playful clean up routine. “You know, clean up, like, try to, you know, stop class ahead of time, check the floor..” (Mary).

Sandra argued that the nature of student work in her STEM class required a longer transition period at the end of class than most other classes:

> The time flies by, but I think we have to allow like ten minutes because eight minutes isn't cutting it. Eight minutes in other classes is plenty of enough time.

Eighth graders attended STEM daily, which allowed for a richer curriculum. However, Sandra only met with sixth and seventh graders every other day and she found it difficult to maintain momentum with these students or go in-depth with concepts or projects. Therefore, the schedule forced Sandra to plan a bare bones curriculum for sixth and seventh graders focused more on skill building than conceptual learning or creative problem solving.

> [F]or sixth and seventh grade, okay like robotics is a unit, and then it's design and problem solving so we have eleven classes of robotics and eleven classes of design and problem solving because that's all I have with them (Sandra).

In addition, the schedule created a situation where, starting in seventh grade, Sandra’s students' requisite knowledge and skills for STEM could vary widely, and this was another factor that influenced Sandra’s curriculum planning. The range in skill levels was caused by STEM’s classification as a grade level elective. It was scheduled so that students only attended class with students at their grade level, however, they were not required to commit to a three-year sequence. Therefore, Sandra could have seventh or eighth graders that had never taken STEM.

Mary’s class schedule was even more complicated. Technology was categorized as an enrichment class for grades one and two, a special for grades three through five, and an elective for grades six through eight. Mary met with each of her classes, grades three through eight, twice

a week and occasionally met with first and second grade classes. Although Mary's middle-school-aged students had much more making experience than Sandra's by sixth grade, like Sandra, Mary could not assume that all seventh and eighth graders had exactly the same level of requisite skill since students might choose not to take technology every year. Mary's approach to curriculum planning, which she used for all grade levels, seemed to work around this problem. Mary designed units for sixth, seventh, and eighth grade classes that were as exploratory and open-ended as possible. To achieve this, she organized projects around the exploration of materials. In comparison, Sandra's projects were less open-ended because she organized them around content, such as robotics, which created the need for more specific learning objectives (although she did not grade students based on these objectives). One could say, therefore, that Sandra's curriculum for her STEM elective was more closely adapted to the grammar of schooling (Tyack & Tobin, 1994), while Mary's technology curriculum was more of a creative "work-around." As I mentioned in Chapter 4, Mary seemed to be adept at navigating the grammar of schooling to make it work for her as much as possible.

Eli's fourth grade social studies classes were scheduled as homeroom cohorts that stayed together throughout the day. School policy imposed limits on grade level cohort and homeroom sizes; therefore, each of Eli's four fourth grade classes contained sixteen students. Mary's grade one through five classes were also scheduled as homeroom cohorts; and although Mary's school did not cap student enrollment by grade level, these classes were reasonably small, 22 students on average, and consistent in size. Mary and Sandra's middle school classes varied greatly in size. For example, during one of my visits with Mary, I observed a sixth grade class with 26 students and another with 13. The reason was that both schools scheduled sixth through eighth grade students as individuals—a scheduling practice that accommodated tracking and also

afforded students the option of taking electives. An unintended consequence was uneven class sizes.

Based on my interviews with Sandra and Mary and what I observed during my visits, it seemed that class size affected expectations of safety and class climate in multiple ways. For example, it influenced overall class dynamic, individual student behavior, how students grouped themselves at tables, and how students traveled around the classroom space. For example, in Sandra's smaller classes, I observed that boys and girls were more inclined to sit in same-sex groups. Larger groups seemed to experience more collisions—which might have been hazardous had they been carrying sharp tools. Class size, Sandra argued, "impacts [students] a lot in an unstructured environment when people move around."

Sandra contended that there was an ideal class size for a school makerspace that ranged between eighteen and twenty. When there are fewer than eighteen students in a makerspace, Sandra contended, it creates a completely different dynamic:

> [T]here aren't as many students to help each other. I find that the smaller classes...actually need more [teacher] help…They don't have enough other people who are able to help...Like that one class where the boy you said was like the second teacher. He was absent the next [class] and the kids were lost without him (Sandra).

In fact, when I attended Mary's two very different-sized sixth grade classes, I noticed that the larger class was very lively, and the smaller class was almost completely quiet with at least one student choosing to work by herself. It appeared to me that Mary had to work harder to keep the students in the smaller class motivated.

As Sandra posited, students engaged in making need a classroom space that will accommodate their movements as they work in a relatively unstructured manner with a variety of

materials and tools stored in different parts of the room. Teachers need storage capacity for a wide range and large quantities of tools and materials. They also need storage space for ongoing student work. Mary and Sandra needed enough space to store the in-progress work of as many as 200 students. None of the three teachers' classrooms were ideally suited, and the space constraints forced all three teachers to set limits on student options for projects. Mary had entertained the idea of setting up stations in her classroom, thinking it might solve some of her space issues:

> Mary: I would need a better organized workspace. I would love to have kids involved in, in one sense like, station work... I would set it up as centers where there would be multiple things happening at the same time rather than everybody doing the same thing at the same time… But the problem is because I work with so many different grade levels, organization-wise that would be a nightmare for me. So, this is why we kind of do things lockstep.

What Mary meant by *lockstep* was having all students in a class working on the same project at the same time within the same timeframe. I observed lockstep projects in all three teachers' classes. While I could see that Mary, Sandra, and Eli provided many opportunities for students to make choices while they engaged in making, none of the projects were based on a student-identified problem or student interest. Sandra, also, had considered setting up stations in her classroom:

> Sandra: Yeah, I would love [stations], but I think that would also have to be a complete change in scheduling to have that. I don't feel like I would even do that with 6th and 7th grade because I see them so infrequently, but you know students that I have, maybe every day for a marking period or like the 8th graders…

Stations would make more sense, in Sandra's view, if students were coming to her class every day to work on their projects, because it would justify leaving projects out. Even so, she anticipated that students passing through her classroom during the day would disturb other students' projects, take materials without permission, or use materials inappropriately:

> Like, I can't leave rubber bands out because they disappear and [kids are] using them for other reasons, usually. Um, I don't give out balloons. For those kinds of reasons—unless it's got a specific use. So, I never feel like I can leave that stuff out and available.

In regard to the schedule, in addition to the constraints on implementing stations that Mary and Sandra described in relation to the number of times a week they met with groups of students and the number of grade levels they taught, the teachers also reported having to contend with transitions between grade levels, and related materials, throughout the day. The Maker Movement literature claimed that mixed-age groups is the ideal model for scheduling makerspace learning so that older or more experienced students can take on the role of expert (Halverson & Peppler, 2018). If that is indeed the case, then perhaps combining stations with mixed-age groups could alleviate some of the teachers' logistical challenges—if they taught one general making curriculum and all students used the same materials. However, K-8 schools typically do not support that model. In accordance with the grammar of schooling, Mary and Sandra's students were scheduled to attend classes with grade-level peers. Further, Mary and Sandra's schedules were organized so that they each met with a variety of grade levels each day. Therefore, Mary, for example, could have a third grade class followed by a fifth grade class followed by an eighth grade class followed by another third grade class. This meant that she and her students had to take out and put away entirely different sets of supplies every 45 minutes, as

did Sandra. Therefore, employing stations could make supply management easier or harder, depending on whether or not the teachers used the same stations for all grade levels.

Eli only worked with one grade level and saw each of his four classes every day, but he still faced similar space challenges:

> I… enter the year with an empty shelf for each homeroom that I have. I have four of them. I have four classes coming through. I try to be as minimal as possible.

In regard to school supply procurement routines, although ordering in large quantities once a year can save school districts money, it leaves teachers like Mary, Sandra, and Eli with little flexibility to purchase the wide variety of materials they would need to support student-directed projects—unless they use their own personal funds or, as Sandra did in her first year, bring materials from home. Grant money helped Mary and Sandra, but grants were intended for one-time bigger ticket purchases, like 3D printers or a class set of Keva Planks.

Mary worked around this problem of having to order materials in advance by filling her classroom with different kinds of open-ended materials such as toy blocks and building systems, such as K'nex, Legos, and Keva Planks, and building a curriculum around them. Sandra also had a workaround, which was ordering pre-packaged design challenge kits that she could use flexibly and mine for materials. This helped limit the range of supplies needed because all students would be working on a similar kind of product.

Eli and his students supplemented the classroom materials he ordered with donated materials that students brought to school. These materials included plastic and metal bottle caps, twist ties, and pieces of cardboard. Eli could also get supplies from the art room or the main office. For example, during one of my visits, Eli sent a student to the office for a box of small binder clips that Eli suggested the student use as game pieces. Despite the three teachers'

creativity in finding materials that could be used in a wide range of ways, the kinds of creations students might produce were limited by available materials and tools. Given all the constraints associated with the grammar of schooling, Eli was skeptical that schools could support 'real' making:

> In a lot of conversations I've seen about makerspaces, it's more just kind of like experimentation and things like that. And in my experience, because I haven't necessarily seen a successful [school] makerspace, that is really like me at home fooling around with things on the weekend or, like, playing with my daughter, which I love, and I would love to see a place in school for that. I just don't think I have seen a successful one yet… I don't think the time is given to it…like scheduling needs to be made available. Resources. Space… and I think that's a challenge for a lot of schools.

A Lack of School Leadership Hindered Fidelity to Maker Movement Practices

Administrators at the three schools I visited indicated support for the inclusion of making in a range of ways from not objecting to it to praising teachers for taking the initiative. However, there was little evidence of the kinds of administrative leadership needed to legitimize the teachers' maker curricula and practices. None of the teachers in my study had been approached by school leaders to develop a shared vision for maker education or discuss how to scale it up within the building or beyond. Instead, Mary, Sandra, and Eli took it upon themselves to practice informal leadership of maker education. Although they appreciated the trust and academic freedom that this benign neglect implied, all three teachers feared this delegated responsibility could cut both ways. First, the teachers worried about possible repercussions from administrators or parents if any student should leave class injured, frustrated, or upset, and this apprehension seemed to foreground instructional planning. For example, Eli decided not to use small knives

and saws with his students after an administrator expressed concerns about it. Although he believed his fourth graders were capable of using the tools safely, he did not feel confident that his administrators would support him if a student injury occurred:

> I asked permission just to make sure, and I had a couple groups of kids building model dugout canoes for our Lenape project, so they had chisels and woodworking tools, and I was bringing them home at night to burn out the middle of the dugout canoes… but like, I could definitely tell as the project went on the administration was worried (Eli).

For similar reasons, Sandra felt she had to make judgments about which groups of students were mature and trustworthy enough to use potentially hazardous tools. Sandra suspected that her STEM class sometimes attracted students disposed to off-task or impulsive behavior. As a non-academic elective, STEM did not count toward the honor roll in her building and students could choose to take it as a PASS/FAIL class. The unstructured class format allowed for socializing with peers and Sandra believed that these social opportunities were the main attraction for some students. Sandra worried that less-focused students might cause accidents if given access to certain tools; and if a student injury occurred, she feared she would feel responsible and that parents would hold her responsible. Although her principal was responsive whenever called upon for assistance with an egregiously off-task student; it did little to alleviate Sandra's anxiety. She believed a more permanent solution to off-task behavior resided in making STEM an honor roll-eligible academic course that would attract more self-motivated students. Also, if STEM attracted academically-oriented science and math students, it might be possible to align curricular goals with the high school's selective STEM Academy:

> Sandra: I feel that we're battling is...the respect for [this] type of [hands-on] class.

> Me: That's having it listed as an honor roll...or have it listed as an academic class, basically?
>
> Sandra: I think so. I mean we have a STEM Academy in the high school that students have to test into and be recommended for, so if it's that important and a big buzz word…if they're in the STEM Academy, they have to be in all honors classes. Then I feel like, well what happened in the middle school?

Sandra's goal was not so much to make her STEM class less accessible; she simply wanted to change the perception that STEM was a "blow off class," or one that students did not take seriously and thought they could pass with minimal effort. She believed that only considering performance in academic courses for Honor Roll inadvertently created some of the disciplinary issues she had to deal with. It also reflected on the status of making in the school and her identity as a teacher who engaged students in making.

The risk of using knives and other potentially hazardous tools was not an issue in Mary's class simply because she avoided them altogether, preferring to use familiar and accessible low-tech materials like Legos, K'nex and other types of building blocks with her students. "I don't have the patience for that, nor do I have really the interest in kids sawing in here plus… the situation I'm in, I can't set up.. a wood shop in my room…" (Mary). Instead, Mary worried about the repercussions of students getting frustrated and upset during class and then leaving her classroom still feeling that way. Making, ideally, provides students with opportunities to experience failure and frustration (Martinez & Stager, 2013). Because making is such a social activity, students working together might experience disagreements or misunderstandings or bring pre-existing social issues with them into class. For these reasons, Mary was always vigilant and made an effort to encourage students who seemed unhappy. Her concern about student

frustration originated in her caring connection with students and desire for them to feel successful. However, she also felt the need to protect herself. As a veteran teacher and the only technology teacher, she believed that she enjoyed a considerable amount of academic freedom compared to other teachers in her building. This privileged position, she believed, was partly contingent upon her ability to keep students happy and engaged. As long as nothing negative happened in Mary's class that could draw attention and scrutiny from parents or administrators, Mary could continue to enjoy the autonomy she had:

> You know what, my administration, they have no idea what goes on in this room. They could give two ____, quite honestly, as long as the kids leave here happy and they don't get parent phone calls, and they don't.

Concerns about student safety also prevented Mary, Sandra, and Eli from facilitating student relationships with adult practitioners in making, design, or engineering outside the school organization who could potentially help students develop their ideas and provide them with access to the greater maker community. Networking, collaborating, and open-sourcing facilitated by the Internet and social media are practices widely encouraged by the Maker Movement but not typically supported by school policies and norms.

School Structures and a Lack of School Leadership Hindered Teachers' Efforts to Collaborate with Colleagues

Collaboration among teachers is important for a number of reasons (Burke, 2017; Johnston & Tsai, 2018). Most relevant to this study is the value the Maker Movement places on collaborating as an essential practice that students can learn from teacher modeling (Charney, n.d.). Collaboration in the makerspace elevates the maker's voice, cultivates agency, and makes learning fully participatory (Hamidi & Baljko, 2015). In the school setting, teacher collaboration

can also facilitate the integration of making into other parts of the curriculum and further empower teachers to effect change in their schools (García Torres, 2019).

Although Mary, Sandra, and Eli wanted making-centered collaborative relationships with teachers in their buildings, they understood that they would likely have to do the promotional work and staff development needed to create those kinds of opportunities. A major hindrance was the lack of available time. All three teachers had full schedules and there was no common prep time for teachers. For example, Mary had seventeen different groups of students ranging from second to eighth grade in her weekly schedule, so even if there were other teachers interested in implementing maker education, which she doubted, she believed that the limited amount of planning time in her schedule would make it difficult to coordinate a regular time to meet with someone else. Sandra also felt constrained by a busy academic schedule, but if she could find the time, she was willing to teach colleagues how to use any software applications or tools they might need. “I could do something like, “Maker Mondays” ... or “Tuck Tuesday” and have, after school, anyone who was interested…” Sandra’s maker curriculum was more technology based than Mary and Eli’s, with more ongoing robotics and 3D printing activity. Teachers would likely have to learn the technology in order to be able to collaborate with Sandra, which might be an obstacle given the lack of time available to them.

Mary and Sandra’s teaching position and their classroom location in the school building also played a role in their access to potential collaborators. Mary and Sandra were specialists, and their classrooms were off the beaten path. Mary’s was located in a back hallway, and Sandra’s was in the basement. Most of the academic teachers that Mary and Sandra shared students with were located together in more central parts of the building. Neither Mary nor

Sandra had the time or reason to travel through the main hallways of their schools, and this prevented opportunities for random interactions that might have facilitated new connections. In addition, although Mary felt that her general education colleagues respected her work, she was certain that no one in the building really understood what making was. “I don't think the teachers have a clue what I do in here,” (Mary). The classroom teachers who walked their students to and from technology class regularly joked with Mary about how much their students looked forward to her class. They claimed that students would watch the clock and shout out “Ok, Mrs. ____, it's time to go! We got to go to tech!” (Mary). Even so, the classroom teachers rarely asked Mary questions or seemed interested in knowing more about what Mary was doing with the students in her room:

> [M]y colleague next door who's the music teacher... and we have the art teacher over here...we're kind of the weird wing that nobody really wants to even go there, you know?”

Mary and Sandra’s lack of opportunities to make potential collaborative connections suggest that assigning STEM or technology instruction to one course or teacher could be an impediment to the integration of these concepts and skills into other courses or content areas. Brown et al. (2010) theorized that isolating staff members prevents the flow of knowledge among the entire staff. Unfortunately, placing teachers in silos by content area is common practice in the grammar of schooling (Tyack & Tobin, 1994).

Eli was able to create a few opportunities to connect with other teachers. As an elementary classroom teacher, he had a grade level team that he met with regularly and he also had regular informal access to a number of other colleagues he might bump into as he walked his homeroom fourth grade class through the hallways each day to and from specials, recess, and

lunch. Often it was in these quick, casual exchanges that ideas were shared and plans for further discussion were made. That said, Eli was still somewhat isolated as a teacher who included making in his curriculum. Although he had established collaborative relationships with the science and art specialists and, to an extent, with his fourth-grade-level colleagues, because he was the only social studies teacher in the building who was actively trying to implement making, he was the sole idea generator for his academic discipline.

There seemed to be costs and benefits to the isolation, or marginalization, that each of the three teachers experienced within their school building. Mainly because they taught "untested" subjects, or content areas not measured by standardized testing, their work was monitored less, and in Sandra's case, treated with less importance than other academic subjects (Spillane et al., 2011). Mary and Sandra might have had fewer opportunities to interact with other teachers due to their marginal locations and busy schedules, but because they did not teach core academic subjects and their administrators left them alone they felt free to innovate, more so than Eli, within the parameters of fixed school structures.

How Teachers Defined or Approached Making, the Materials, and the Type of Space They Used Seemed to Have an Effect on Student Engagement and Collaboration

The three teachers in this study varied in how they defined and implemented making in their classrooms. For reasons that I discussed earlier in this chapter, none of the teachers implemented making in a way that matched how they would like to implement it or believed it ought to be implemented, given the constraints associated with both the Discourse of teaching (Gee, 2014) and grammar of schooling (Tyack & Tobin, 1994). However, as I discussed in Chapter 2, there is no real consensus on a definition for making. In fact, definitions of making located in the academic and popular literature have grown more inclusive of different kinds of

activities and materials over time (See Chapter 2, Table 3). Nevertheless, the Maker Movement literature identified three predominant types of activity that might be observed in classroom makerspaces: making, tinkering, and engineering (Martinez & Stager, 2013). Making is described as the creation of something new mainly to gain a sense of ownership or self-efficacy. Tinkering is a playful way to approach and solve problems through hands-on experimentation and discovery. Engineering involves extracting principles from direct experience and using these new understandings to make the world explainable, measurable, and predictable. The Maker Movement literature suggested that, although a student's problem-solving process might not be quite so clear cut, engineering is associated with a formal iterative design cycle and planned outcome, while making and tinkering involve informal, open-ended trial-and-error problem solving processes and creative exploration of materials (Resnick & Rosenbaum, 2013). The three teachers in this study indicated that while they would prefer to engage their students in open-ended making and tinkering activities, certain teaching practice norms and formal school structures limited their options. Taking an engineering approach to making would have afforded the teachers with predictable student outcomes and an observable thinking process that the teachers could assess. An engineering approach would also have provided more opportunities to align curriculum with state technology standards. However, the projects Mary and Sandra assigned their students seemed to involve a blend of engineering, making, and tinkering. Mary and Sandra simply called it "play." Mary also described it as "kindergarten for teenagers."

It seems that the materials and tools the teachers made available for students as well as features of the classroom space influenced what "play" looked like in their classes. Mary's core materials—K'nex sets, Keva planks and Legos blocks—which she thought to be familiar toys and therefore highly accessible to her students—met students at their readiness level and allowed

them to be creative on the spot. Because most students were familiar with these types of connecting and building blocks, and many had them at home, there was little to learn before using them as tools for creative work. This was also true about Eli's core materials: paper, cardboard, bottle caps and other found recycled materials. These, too, were materials most of his students had used creatively for most of their lives. In Mary and Eli's classrooms, "play" seemed to happen fluidly. Although there were occasions when students tried to take charge, disagreed with members of their group, or grew annoyed by students in other groups, for the most part, there was a steady hum in both Mary and Eli's rooms as students worked together contentedly. The fourth graders I observed in Mary and Eli's classes, and Mary's younger students, seemed to collaborate almost completely nonverbally. Although there were occasional disagreements within or between groups; they most often worked quietly and except for the occasional half-uttered sentence, it appeared as though students were communicating by reading each other's minds. The sixth, seventh, and eighth graders I observed in Mary's classes were much more verbal in comparison. They would ask for each other's opinion or give suggestions while also engaging in banter and idle chatter about topics unrelated to their projects.

Mary shared some thoughts about how the tools a teacher makes available might influence students' learning:

> I'd prefer [students]...to experience [making] maybe how I'm teaching it because I don't think it frightens kids. Because, I mean, some of the [technology] and building, a lot of kids don't have experience with that and...so I…try to make it as pleasant as possible because... if you do try to make it more sterile in a way, I think it can frighten kids and frankly turn them off… [H]onestly, for the most part, every kid that I've ever taught has enjoyed my class.

In contrast, Sandra's core materials included various 3D modeling, CAD, and beginner's coding applications, robots, 3D printers, electromagnets, balsa wood, wood carving tools, hand saws, vices, hand drills, mechanical weighing scales, and T-squares. For most students in Sandra's STEM classes, these were unfamiliar materials or tools, so she had to spend some time at the beginning of class introducing them. Once she distributed them, student "play" sometimes seemed to center on the new materials and tools themselves. On many occasions, I noticed a few students studying and handling a new tool with fascination and playing around it for a relatively long period of time before trying to do anything creative or productive with it. A frequent student behavior I noticed during one visit to Sandra's class was waving and slapping a flexible T-square in the air or whipping it against a piece of furniture. There were a few students who seemed to have trouble moving on from this novelty stage with tools and contributed little to their project. In Sandra's view, this tool-centered play was off-task behavior.

It can be hard to delimit the boundaries between on and off-task behavior in a less-structured learning environment. As in any classroom, it can totally depend on the teacher's comfort level, unless the teacher involves students in the design of classroom behavior expectations. Sometimes, identifying whether a particular student's behavior is on- or off-task can depend on how well the teacher knows the student. It could be, also, that notions about desirable and undesirable behaviors need to shift according to classroom design and instructional delivery method (Brooks, 2012). That said, in general, I noticed that Mary and Eli's groups of students seemed to be more often highly engaged in independent creative work that was aimed toward a specific goal, or "in the zone" as Mary would say, while individual students within Sandra's classes were frequently engaged by their tools or by each other's off-task behavior.

Sandra's classroom management skills were similar to Mary and Eli's. She set learning and behavior expectations at the beginning of each class and kindly gave students reminders as needed. It is possible, then, that Sandra's students might have needed more time to familiarize themselves with their new tools before attempting to make something new with them, as Bruner's (1960) spiral curriculum theory might suggest. Unlike Mary and Eli's students, Sandra's sixth grade class was the first time students got to experience making, and "[STEM] was a completely different type of class for them" (Sandra). Perhaps if Sandra's students had come to her class with previous experience in robotics, 3D printing, and with some of the other tools she liked to use or more experience with student-centered and task-centered instruction, Sandra would have encountered less "off-task" behavior (Bruner, 1960).

Sandra's classroom space differed considerably from Mary and Eli's (see Appendix D; see also Appendix B; E), and this could have influenced student behavior as well (Brooks, 2012; Duncanson, 2014; van Merriënboer et al., 2017). What is traditionally defined as off-task behavior tends to be more frequent in non-traditional classroom spaces (Brooks, 2012). Also, a misalignment between the design of a learning space and how it is used can undermine learning in different ways (Duncanson, 2014; van Merriënboer et al., 2017). Mary and Eli's makerspaces were created in typical elementary classrooms: rectangular-shaped rooms with dropped ceilings and fluorescent lights, a clearly defined instructional center with a whiteboard and an interactive electronic whiteboard at one end, desks or tables and chairs in the center, and windows running along one side. In comparison, Sandra's space was a former wood shop designed for task-centered learning (van Merriënboer et al., 2017). It was pentagonal in shape with high ceilings, industrial pendant lights, and several built-in countertop-height butcher-block workstations with tall wooden stools. Each workstation could seat as many as eight students. Vice grips were

installed on opposite ends of each table and a retractable power socket hung above each workstation from the ceiling above. As in Mary and Eli's classrooms, there was a wall with a whiteboard and an interactive electronic whiteboard near the workstations, but Sandra rarely stood in that area. She more often addressed the class while standing in the center of the room. It is possible that some students experienced Sandra's classroom as another unfamiliar tool. For example, I frequently noticed students fidgeting with the vice grips and their stools. In contrast, Mary and Eli's students seemed to ignore classroom furniture and features of the classroom space as if they were invisible.

Possibly, an absence of explicit instruction in collaborative skills, a lack of feedback or reinforcement directed specifically to collaborative skills, or less experience with collaborative learning across the curriculum might have influenced student small group behavior in Sandra's class. Sandra's remark that her STEM class was a totally new kind of class for students lends some support for this idea. Of the three teachers, Eli appeared to be the only one who actively taught collaborative skills. Effective collaboration is something that must be taught; teachers cannot assume that students will work productively in small groups without explicit instruction (Sparks, 2017). Using different versions of the cooperative learning model, Eli provided structure to the students' small group work (U.S. Department of Education, 1992). He consistently gave explicit instructions so that students working together could understand what the group goal was and also what their own roles and responsibilities were in supporting the group's learning process.

A Teacher's Definition or Approach to Making Shaped How the Teacher Generated Collaborative Opportunities

Although school structures such as the schedule and location of classrooms seemed to limit the three teachers' opportunities to develop collaborative relationships, it seemed that having a more inclusive conceptualization of making was a way that teachers could improve their chances without having to rely on school leadership support. Of the three teachers in this study, Eli had participated in the most collaborative interdisciplinary partnerships with colleagues. It seemed that Eli was able to make making more accessible to a larger population of colleagues because he took a low-tech approach and provided a broader representation of making in student projects, which included writing. Eli's definition of making emphasized making meaning above all else, and in his view, students could make meaning without having to build anything. Planning interdisciplinary projects with the science and art teachers seemed to happen more easily since they were already engaging students in making, but Eli's acceptance of writing-as-making enabled him to attract a collaborative partnership with the fourth grade language arts teacher:

> [T]he rubric we give the kids is half content for social studies, half language arts skills and we divide it up that way. [T]hey work on it in both classes... I.. do all the historical background and then Mrs._____ takes over for the editing.

Mary and Sandra, in comparison, did not have collaborative partnerships like Eli's. They attributed this mainly to a busy schedule and colleagues' lack of interest in maker education. It is possible, however, that Mary and Sandra's concept of making, which was more design oriented, and their more specialized materials and tools might have inadvertently made making seem less accessible to other teachers. Indeed, Sandra suggested that she might have discouraged some of

her colleagues with her STEM curriculum's heavy emphasis on technological tools that required a considerable amount of time to learn, such as robotics and 3D printers.

Teachers Foregrounded 21st Century Skills and Social-Emotional Learning

All three teachers believed that the most important maker education outcomes were the *soft skills* students developed, as Sandra indicated below:

> [P]roblem solving, collaboration, critical thinking, because they don't get that practice anywhere else or not a lot of it. They want to be told what to do. And I really have seen that a lot, even recently... This doesn't work! I don't know; what should I do?! What should I do?! What do you think you should do? (Sandra).

Encouraging these soft skills was an essential part of enculturating students as makers (Brown et al., 1989), or in other words, introducing them to the making Discourse (Gee, 2014). Once enculturated as makers, students would have the appropriate social practices in place to make successful connections with other makers in other physical and online spaces. Mary explained that she found the soft skills to be most valuable and enduring aspect of making:

> [T]he kinds of skills that it brings... while you're making something… What's going into the making, which is probably even more important than the making. Because what goes into it is timeless... It doesn't become obsolete: communicating with someone or working together, having a plan, having end results, you know…

In addition to fostering soft skills development, the three teachers indicated that they intentionally cultivated a classroom climate where students felt they could relax, be creative, take some ownership, and take some risks without the fear of academic consequences if they failed. To some degree, this choice reflected a political stance the teachers had taken. All three tended to push back against formal school structures and routines that they believed compromised student

wellbeing. Eli, for example, disagreed with routines and attitudes that he believed subjugated students, such as making students wait in the hallway outside the classroom if no teacher was present. In Eli's view, this routine undermined students' sense of community and ownership of their classroom space. In response, he permitted his students to enter his classroom whether he was present or not. To better ensure student safety in the classroom while unsupervised, Eli collaborated with his students to develop a set of community expectations so they could have a voice in the kind of classroom atmosphere they wanted. As a result, Eli believed his students felt empowered to hold each other accountable to those agreed upon standards:

> Like, if they're, if things come up and we can't follow our class goals and guidelines then we'll deal with that, but this is your space as much as it is mine as long as you treat it respectfully. And I think that message gets across, like they feel ownership in it, and I think it makes for a space where they're comfortable taking ownership of their things and, like, creating within it.

Mary and Sandra acknowledged that the safe emotional space they had fostered in their makerspaces was a subtle form of protest against the academic pressures they believed their upper elementary students experienced on a daily basis as a result of high stakes standardized testing. Because their classes were not subject to testing, Mary and Sandra felt they had the latitude to implement curriculum in a more relaxed fashion and provide room for students to learn important life skills that they believed were under taught in the current accountability climate. They used what freedom they had to help bring some balance to their students' hectic lives. Mary believed many of her students found her class to be therapeutic:

> [There's] a class called 'wellness' that's run by the health teacher...One kid just summed it up. He said, "This class should be called Wellness" <laughs>. He said, "Because we

> get to relax, we get to talk, we get to work with each other...and just gonna do. And you come in and it's fun."

For all three teachers, this freedom to turn their classroom makerspaces into sanctuaries for students was one of the major benefits of teaching in the margins, under the radar, in relative isolation.

Chapter Summary

This chapter described ways in which school structures and school leadership supported or constrained the three teachers' efforts to engage students in making. In keeping with grammar of schooling theory (Tyack & Tobin, 1994), institutionalized organizational structures and routines that have historically defined schools created obstacles for the teachers in their attempts to introduce new practices. Interestingly, Eli was just as constrained by his school context as Mary and Sandra, despite teaching in an independent school. Eli's struggles to include making in his fourth grade social studies curriculum suggest that even in the absence of standards-based reform pressures and other forms of state regulation, independent schools can still be constrained by the legitimizing grammar of schooling as they compete with public schools for students.

When the teachers felt supported, it was mainly due to the collaborative support of other teachers, grant funding for materials provided by parent-run educational foundations, or parent praise. There seemed to be a notable lack of leadership, or benign neglect, that created costs and benefits to teachers. Costs included chronic feelings of fear, anxiety, regret, and isolation because teachers felt torn between the teaching and making Discourses and lacked a validating community of practice. Without validation, the teachers feared criticism or censure for a lack of fidelity to teaching norms. Benefits included a sense of freedom to redesign their classrooms as makerspaces, develop maker identities, design curriculum, and conceptualize their makerspaces

as sanctuaries for students that provided social and emotional balance against school structures and authorities that the teachers believed were unfairly imposed upon them. In the public schools, these structures and authorities included hectic academic schedules that left little time for students to socialize and the tacit pressures of standardized testing. In Eli's independent school, it was a traditional authoritative school culture that subjugated students. From their marginalized spaces, Mary, Sandra, and Eli pushed back against structures that they believed did not serve the best interests of children. They also found ways to find creative enjoyment in teaching and share it with their students.

This chapter also illustrated opportunities for leadership that could facilitate the efforts of teachers who engage students in making. Creative scheduling, pragmatic approaches to assessment, and support with building collaborative relationships are just a few. In sum, principals and superintendents are in a position to help mitigate constraining structures and routines.

Interestingly, Eli's reluctance to identify as a making teacher because the science and art teachers had promoted a technology-centered definition of making suggest that teachers' conceptualizations of making might be subject to dispute. This could create additional tensions in a school building as more teachers begin to include making. Therefore, Eli's situation indicates another leadership opportunity. Collaborating with teachers to proactively develop an inclusive definition of making might encourage more teachers to adopt making practices and facilitate collaboration. Also, Sandra's issues with student behavior suggest that the possible effects of unfamiliar types of learning environments and learning tools on student engagement are worthy of attention. School leaders might consider that waiting until middle school to introduce students to a makerspace setting might inadvertently set students up for cognitive dissonance.

Chapter 8: Conclusion

This study investigated three questions: *1) In what ways do three teachers appear to be conceptualizing making with students?; 2) In what ways are three teachers implementing making with students?; and 3) To what extent do claims regarding "good maker teachers" pan out within three actual school-based contexts?* It also sought to understand how the teachers navigated the norms of the Maker Movement, their school contexts, and the field of N-12 education. In this chapter, I begin by summarizing the main findings of the study, then I compare the findings to claims from the Maker Movement literature that I reviewed in Chapter 2 and describe this study's contribution. Finally, I describe the implications for school and district leaders, researchers, teacher educators, and policymakers.

Summary of Findings

Teachers' conceptualizations of making. The following Table 6 outlines the three teachers' conceptualizations of *making* in addition to their conceptualizations of *maker* and *makerspace*. Like the more recent definitions of maker and making in Tables 2 and 3, the teachers' definitions omitted any reference to specific tools or materials and instead foregrounded the person and personal processes such as learning and creativity. Eli's seemed to be the most inclusive.

Table 6

Teachers' Conceptualizations of Maker, Making, and Makerspace

Teacher	Conceptualization of maker	Conceptualization of making	Conceptualization of makerspace
Mary	Someone who has been allowed to play and finds value in tinkering	Using hands Remixing ideas	A place where there are materials available; maybe things students have played with as children
Sandra	Someone who has a vision and can follow the design cycle to create a prototype.	Tinkering; gathering stuff and making something new	A room with designated areas or stations where students can work with materials in a self-directed fashion
Eli	Anyone, given the right opportunity, materials, and belief in themselves.	Making meaning	A space for open-ended work and experimentation

Interestingly, the three teachers' conceptualizations of makerspaces differed significantly from their own classroom spaces. None of the teachers believed that their classroom makerspaces had the capacity to support the open-ended work of several different groups of students or the storage needed for in-progress student projects and the various materials and tools needed for truly student-directed projects.

Findings of the present study suggested that teachers' conceptualizations of making 1) were influenced by the teacher's background, position, and environmental conditions, such as available materials and space, 2) influenced how the teacher generated collaborative

opportunities, and 3) influenced student engagement with making. For example, Sandra's background in mechanical engineering and position as STEM teacher seemed to influence her inclusion of 3D printing and robotics in her curriculum. Eli's definition of making was the most inclusive and accessible—he considered writing to be a form of making. Also, Eli's positions as a fourth grade social studies teacher and Social Studies Coordinator gave him easy access to the other fourth grade teachers and specialists in the building. As a result, Eli had developed more collaborative relationships than Mary and Sandra. Design of the classroom space and selection of materials seemed to have an effect on student engagement and social learning. Once again, accessibility seemed to play an important role. More accessible learning contexts, like Mary's and Eli's, seemed to engage students more effectively in social learning. That is to say, students seemed to persist more easily with familiar materials, such as cardboard or Legos, in a more traditional type of classroom space. The reason for this, most likely, is that the materials and the appearance of the physical space required minimal new learning, keeping students within their comfort zone, and therefore freeing up their attention so they could focus on creative problem solving.

Teachers' implementation of making. When engaging students in making, teachers emphasized independent problem solving and 'soft skills.' Soft skills included listening and speaking with others, making a plan, using different approaches to solve a problem, and being able to persist in developing an idea or solving a problem despite such challenges as indecision, confusion, or failure. All three teachers were very interactive with students—most often starting conversations with a question. They provided opportunities for students to work alone, with partners, or in small groups to develop independent and collaborative skills. The teachers seemed able to provide just the right amount of guidance and support to facilitate student thinking. As

students progressed with their projects, teachers provided information, suggestions, and materials as needed. More often, this was when the teacher sensed that a student was becoming frustrated enough to lose interest or shut down, could offer a tip that might advance the project, or recognized a teachable moment. For example, Mary described how she sometimes knew exactly which Lego piece was needed to make a student design work. She did not expect students to have this kind of extensive knowledge of her Lego inventory or experience with Legos, so she would share it as needed.

Contextual factors that influenced teachers' making practices in the classroom. Several factors in the school and N-12 contexts seemed to constrain the teachers' ability to implement making.

Tension between Discourses. Teachers experienced tension between accepted teaching and making practices. Feeling pressured to conform to teaching practices while engaging students in making, the three teachers found themselves having to make compromises in their making practices. For example, Mary, Sandra, and Eli felt pressure to plan curriculum in advance, which included creating units of study with desired learning outcomes and assessments. In their view, this compromised the spontaneous, problem-centered nature of making and led to making that was more teacher-directed than student-directed. As a result of compromises of this nature, the teachers felt torn.

This tension elicited a range of feelings, including regret and anxiety, because the teachers believed 1) they were doing neither Discourse justice and 2) feared possible repercussions for not conforming with traditional teaching practices. Yet, despite feeling uncomfortable and at risk, the teachers valued making enough to persist with it. Mary believed engaging students in making was the right thing to do.

Tension between school structures and making. Formal school structures and routines also placed constraints on the teachers' ability to implement making. Structures and routines included the academic schedule, the school calendar, school supply procurement routines, and the classroom space. The schedule created 45-minute periods without sufficient breaks in between for the teacher to prepare the room for the next class. 45-minutes was not enough time for students to become immersed in projects, especially since different groups used the classroom during the day and required that teachers set aside time at the beginning and end of each class for students to gather and put away their materials. As I mentioned earlier, teaching multiple groups of students across the day—and in some cases multiple grade levels—made it difficult to manage and store an abundance of materials and student projects in classrooms that had not been designed for this purpose. The academic calendar, which scheduled breaks between marking periods, promoted a linear view of learning and imposed assessment and reporting cycles that forced the teachers to set deadlines and evaluate their students' making. In addition, school procurement practices forced the teachers to choose materials in advance of the school year. All of these structures and routines made it difficult for the teachers to maintain a spontaneous, open-ended, student-directed learning environment.

A lack of school leadership that supported making. Teachers described a lack of administrative leadership at the school and district level to support and facilitate making in classrooms. Effective leadership could help minimize the impact of formal structures and routines on the implementation of making. The constraints of the schedule could be minimized, for example, if school leaders provided longer class periods for teachers like Mary, Sandra, and Eli, whose students work with materials. Effective leadership could also facilitate and promote the kind of teacher collaboration that Mary, Sandra, and Eli sought and the subsequent

integration of making into other classes. One way to start might be to locate specialists like Mary and Sandra in parts of the building where they could more easily interact and build collaborative partnerships with teachers of academic subjects. Instead, this lack of leadership support marginalized the teachers, relegating them to a state of benign neglect which in some ways liberated them and in other ways fed their anxiety.

Teachers' implementation of making in relation to claims made about 'good making teachers' in the literature. As I outlined in Chapter 2, the Maker Movement literature contains varied speculative claims about the potential benefits of making in schools, why teachers might be motivated to implement making, and how teachers 'should' implement making. For example, the Maker Movement literature suggested that teachers would choose to implement making based on an alignment between making practices and skills promoted in the Next Generation Science Standards (Martin, 2015; see National Science Teachers Association, 2014). The Maker Movement literature also claimed that teachers would recognize the potential for making to attract a more varied population of students into STEM fields (Agency by Design, 2015; Bevan et al., 2015; Obama, 2009) and to this end, makerspaces should possess elements of shop class, home economics, art studios, and science labs (Dougherty, 2013; Schad & Jones, 2020). In contrast, however, the present study indicated that teachers' motivations to implement making and their particular teaching choices in relation to making were mainly personal and contextual. In fact, Mary, Sandra, and Eli had chosen to engage students in making because 1) they personally valued the emotional benefits of making and the learning skills involved, and 2) they thought their particular students needed these types of learning experiences to balance what and how they were learning in other classes.

To begin, all three teachers enjoyed making in some form themselves, even if it mostly manifested itself in their enjoyment of creating curriculum and designing learning experiences for their students. Sandra liked learning about new technological tools related to making and troubleshooting problems, Eli liked "hacking together" units of study and lesson plans, and Mary liked remixing and customizing others' ideas. Further, Mary felt that making with students reinvigorated her teaching. She had been a classroom teacher for 25 years, was often bored, and found that sharing in her students' creativity and enthusiasm made it easier to get through the day.

While the teachers' instructional methods seemed to match descriptions in the Maker Movement literature—for example, Mary, Sandra, and Eli regularly stepped back into a coaching role where they offered suggestions or asked students questions to guide them toward discovery (Bevan et al., 2015; Campos et al., 2019; Chan & Blikstein, 2018; Clapp et al., 2016; Martinez & Stager, 2013)—all three claimed that they had always taught that way and it was partly the alignment between their teaching style and making practices that attracted them to the idea of engaging students in making. In addition, while Mary and Sandra recognized the purpose of curriculum standards in framing the district-level curriculum, standards did not supplant their knowledge and expertise as teachers and were not their main focus when designing curriculum. Mary and Sandra kept standards at the back of their minds, not the front, and more often they looked for a standard to justify a lesson or a unit after they had written it. As an independent school social studies teacher, Eli was not attuned to the Next Generation Science Standards or subject to any standards at all.

A key aim behind makerspace activity, the Maker Movement literature argued, was to engage students in processes of design and innovation so they could produce new things to share

with others (Halverson & Sheridan, 2014; Kafai et al., 2014; Petrich et al., 2013; Resnick & Rosenbaum, 2013). Also, it claimed, making activities should demand that students draw on their own knowledge, take risks with their ideas, and operate on the edge of their understanding like artists, designers, scientists, and engineers (Petrich et al., 2013). Further, teachers should design activities that inspire self-confidence and develop design and entrepreneurial skills that students can immediately apply in the real world (Clapp et al., 2016; NMC & CoSN, 2015) sometimes to address local problems or needs (Blikstein, 2008; NMC & CoSN, 2015). While Mary, Sandra, and Eli certainly did subscribe to many of these ideas, they believed the true value of the makerspace in their school context was its function as a learning environment that was more democratic and less pressured than a traditional classroom space. The teachers placed primary importance on their students' social-emotional safety and wellbeing and recognized the makerspace as a vehicle through which they could cultivate an informal, relaxed atmosphere that supported social interaction, collaboration, and creative risk.

Finally, the teachers chose to engage their students in making because they had identified a compelling lack of independent and social learning skills. In all three schools, many students seemed dependent on teacher affirmation or wanted to be told what to do. The teachers indicated that most students, especially those in grades 6-8, also lacked opportunities to socialize or engage in social learning in other classes. Mary, Sandra, and Eli had taken the responsibility to address this gap in the school curriculum by providing students with experiences that required creative struggle, planning, persistence, productive interaction, and collaboration, to name a few.

Implications

The findings of this study have implications for school leaders, policy makers, teacher educators, and researchers. First, school leaders can support teachers who engage students in

making by validating their maker pedagogy in concrete ways, such as by working with them to envision and plan the future of making in the school. Considering the different perspectives in the Maker Movement literature on the purpose of making, particularly perspectives that categorize makerspace learning as career and technical training or as an extension of college preparatory STEM courses, school leaders might take steps to ensure that making is accessible to all teachers and students, including those who are not focused on CTE or STEM. The collaborative envisioning process might be a place to begin promoting making as an activity that all teachers can facilitate and all students can engage in. School leaders can also provide support by thinking more creatively about the schedule, curriculum and assessment practices, and school supply procurement policies so that they facilitate making practices and pedagogy. Finally, school leaders might consider how the schedule and location of classroom makerspaces in the building might support or impede spontaneous interaction among teachers and the development of collaborative partnerships.

Policymakers might consider how attempts to mandate, standardize, or regulate making in schools might undermine the open-ended nature of making and its social-emotional purposes. Much like recess, if there is evidence that a school activity, such as making, is beneficial to students in its own unique way, perhaps all that is needed at the policy level is to provide for it. Evidence of agency and maker identity in the pioneer teachers in this study suggests that teacher educators might consider focusing on maker identity development as a way to better equip teacher candidates to proactively navigate the contextual forces in schools that threaten to control their teaching practices. This would mean placing greater emphasis on creative struggle, iterative problem solving, and social networking across the curriculum in teacher education programs.

With so few studies, to date, that focused on pioneer teachers who engage students in making, the Maker Movement literature would greatly benefit from increased attention to these teachers and how they practice as makers within the school and N-12 education contexts.

Limitations of this Study

As I mentioned in Chapter 3, as I began data collection for this study, I was aware that my position and identity as a former teacher and tendency to identify with other teachers could limit my perspective at times, so I had to be careful to take detailed notes in case over-familiarity rendered some teaching practices and routines invisible to me. Ongoing discussion about my data with my dissertation committee and critical friends group helped identify important details that I otherwise might have missed. I was also aware that being in the position of learner in regard to The Maker Movement and conducting research, my lack of experience with makerspaces and analyzing data might also cause me to miss what otherwise might be important data or insights in the data. This is the main reason I chose to employ the constant comparative method of analysis, so that I could repeatedly return to the data with a more informed perspective each time. Having three different cases to compare helped bring certain details about makerspace teaching and learning to my attention. My personal interest and enthusiasm about the Maker Movement, sparked by a fascination with 3D printers, as I mentioned earlier, might have predisposed me to see only the positive aspects of maker education or interpret data with rose-colored glasses. Therefore, I made certain to consider the full range of teachers' experiences with engaging students in making during data collection and data analysis. Finally, because the Maker Movement has historically been thought of as an environment for white male tech enthusiasts (see Davies, 2017), as a white female outsider, I made an effort to remain open when examining Maker Movement influences on teaching because it was still somewhat foreign to me and at

times teachers had to explain things to me. However, because of the implied exclusivity within the Maker Movement, I did have to control my bias and critical stance as a white female who is not a tech hobbyist and who is, in theory, excluded from the core membership of the Maker Movement.

Significance and Contributions of this Study

Theoretical contributions. This study is significant because it makes important theoretical contributions to the Maker Movement, self-authoring (Bakhtin & Holquist, 1981), and history-in-person (Holland et al., 2001) literature with 1) its focus on teachers in practice; 2) its focus on various nested and overlapping or in-tension contexts that influence teacher practice, such as the classroom, the school, the school district, the N-12 state and national policy contexts, industries that profit from and support N-12 education, and the Maker Movement; and 3) its focus on contextual constraints and the role they play in teacher practice.

Findings from this study raise the question: Why is it that teachers who engage students in making continue to be motivated to do so despite the frustrations of contextual constraints, added work on top of their expected teacher practices, chronic anxiety and fear related to navigating contexts and Discourses, and personal and professional risks, such as marginalization, harm to reputation, and liability? I argue that teachers develop identities and values as makers in their local context, and that they see both the challenges and the possibilities for autonomy in marginalized spaces. Pioneer teachers who engage students in making care more about student-centered teaching and learning and care less about external motivators and constraints.

Knowledge contributions. Although the Maker Movement literature suggested that 3D printing, tinkering, robotics, and other tech-related activities are common in school-based makerspaces, findings from this case study suggested that not all teachers include these activities

or make them a primary focus. Of the three teachers in the study, Sandra was the only one who included both robotics and 3D printing in her STEM curriculum. However, she described her curriculum as design-based rather than engineering-based. Mary included robotics but not 3D printing, arguing that 3D printers were difficult to work with and time consuming. She preferred that students engage in hands-on work with K'nex, Legos, and other open-ended "toys" so they could continue to add to their designs in real time. Like Sandra, Mary also described her curriculum as design-based. Eli did not include robotics or 3D printing in his curriculum. He allowed students the option to create objects with a 3D printer for certain class projects but did not supervise the 3D printing projects. Instead, the art and science teachers provided support with this. Eli based his making curriculum on meaning-making which included interpreting text and writing as forms of making.

The Maker Movement literature suggested that teachers might be attracted by The Maker Movement and its associated making practices for its potential allure or accessibility to students who might not otherwise be interested in STEM subjects or careers. The present case study shed light on alternative reasons that teachers might value making as a learning activity. In fact, teachers in this study placed more importance on the social-emotional benefits of making than on the STEM content of their lessons or the products students were creating. They also recognized a compelling need for the independent learning, social learning, and problem-solving skills that making seemed to foster.

To date, the Maker Movement literature has produced little knowledge about how teachers think or practice in regard to making in school. This is especially true of non-STEM teachers, like Eli, and pioneer teachers who engage students in making without school or district goals to include making in the curriculum. The present study makes an important contribution by

providing an in-depth description of how three pioneer K-8 teachers conceptualized making, implemented making, and how they asserted their vision and identity in relation to making. The present study also sheds light on the relationship between the teachers' making practices in the classroom and the multiple contexts they had to navigate as they engaged students in making, including the Maker Movement and the constraining contexts of the school and N-12 education.

Future research might focus on how other non-STEM—or non-STEAM—pioneer teachers, like Eli, are implementing making, how other pioneer teachers and their schools are conceptualizing making, the relationship between teachers' implementation of making and student engagement, school leaders who are successfully supporting making in their schools, the relationship between purchased materials and kits that were designed for makerspace learning and teachers' conceptualization of making, and the relationship between formal and ongoing professional development in making, such as through a partner organization, and teachers' identity development as makers. Future study might also focus more specifically on the emotional lives of pioneer teachers as they assert their identities in constrained school spaces.

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Appendix A

Interview Protocol

Name of Participant:
School:
Position:

Initial interview

1) Tell me about your experience becoming a teacher who does making with students. [Prompts: What is "making" for you? What got you into it? Have there been challenges? If so, what were they? What are your thoughts about those? Have there been successes? If so, what were they? What are your thoughts about them?]

2) As you have been working to integrate making into your teaching, what has been your learning process? [Prompts: How have you learned about making? How have you learned to design/set up your space? How have you learned to design lesson plans? How do you assess student progress? How do you assess your own progress as a teacher who does "making?"]

3) Tell me about your teaching. How would you characterize your teaching style? What's your philosophy of teaching? [Prompt: Would you say that this has been consistent, or have you noticed any changes since you started making?]

4) Tell me about your school as it relates to your "taking up" making. [How did you become the maker teacher? What kind of support does the school or district provide for you? For students? What are your colleagues'/school leaders'/ students'/parents' attitudes about including making in the curriculum?]

5) How do you feel about taking on making with students? [Do you see yourself differently now that you've been teaching kids about making [yourself as a

teacher/your role in the school]? Do you think others see you differently now [colleagues/school leaders/students/parents]?]

Second interview (at the end of the data collection phase)

1) If you choose to continue making with students, what lessons from this experience do you think you can take forward with you?

2) In what ways has making influenced your teaching practice? What are your thoughts about those?

3) In what ways has participating in this research study possibly influenced your practice during this period of time? What are your thoughts about that?

Post-lesson interviews

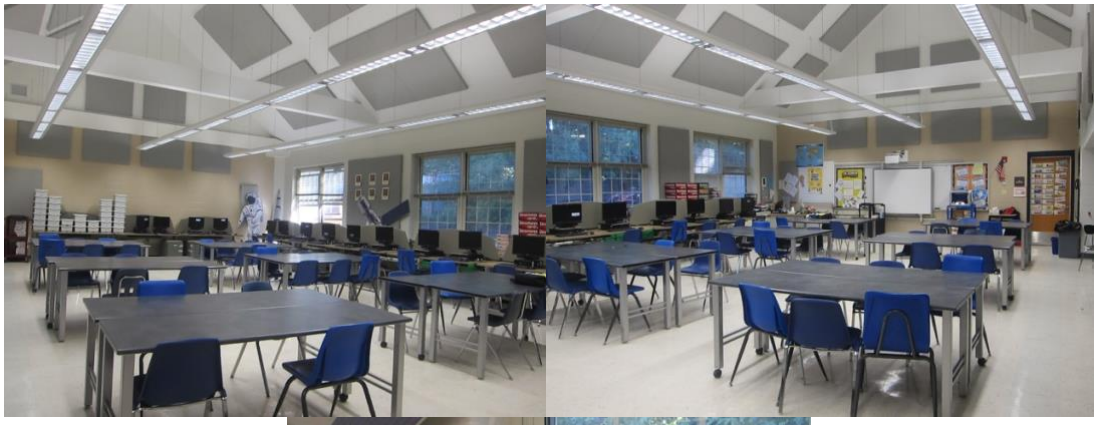
1) Describe any "Aha" moments you might have had during your lesson.

2) If you could go back and do the lesson over, what might you try to anticipate happening during the course of the lesson?

3) In what ways do you feel you managed the lesson well, and conversely, what might you change about your teaching as you go forward with making?

Appendix B

Classroom Makerspace - Mary

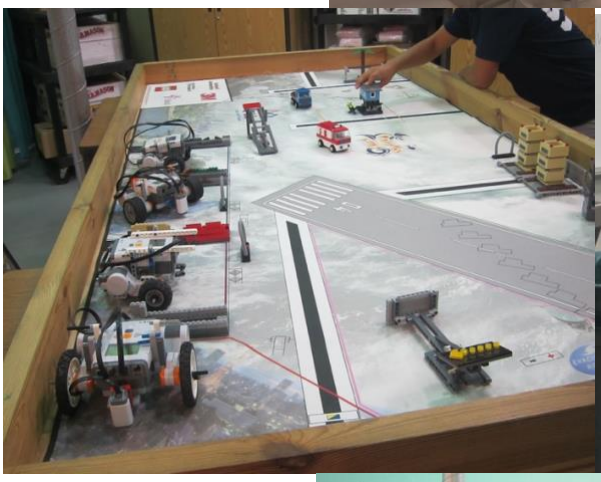


Appendix C

Mary's Supplies

Appendix D

Classroom Makerspace – Sandra



Appendix E

Classroom Makerspace – Eli

Appendix F

Project Rubric – Eli

Number: _____ Name: _____

New Jersey Theme Statement: _____

_____

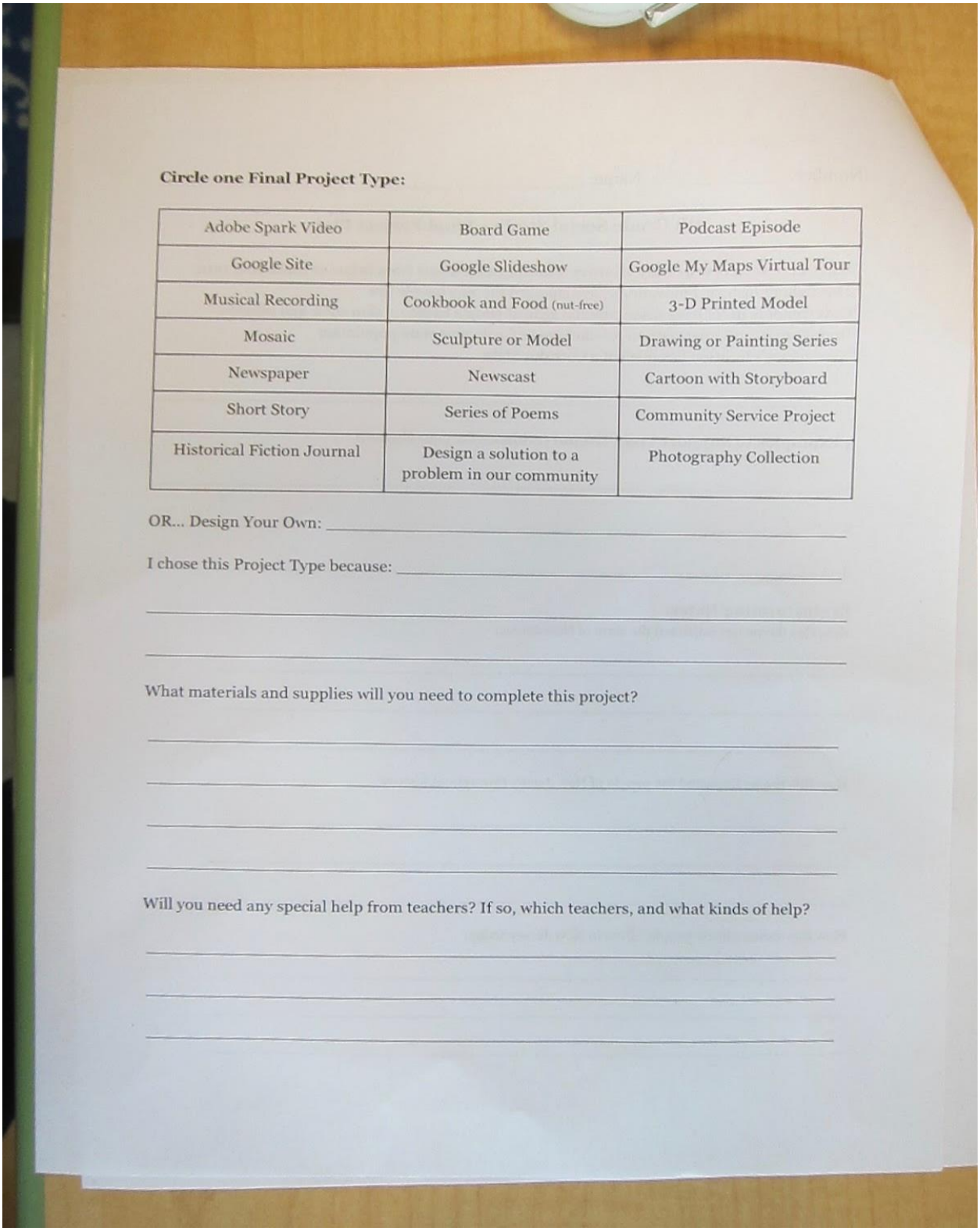
Project Type: _____

4th Grade Final Project Grading Rubric

Project	Points
-Choose a theme and project type -Complete a detailed project plan on time	/10
-Identify & state a theme in New Jersey history -Give 3 or more detailed examples to support the theme -Explain how the theme and each example impacted the history and development of the state of New Jersey -Explain how this theme affects people's lives in NJ today -Explain how this theme affects your life today	/30
-Project represents the theme -Project enhances the audience's learning experience -Demonstrates mastery of skills related to the project type	/20
-Information is accurate and correct -Ideas and information are clear and detailed -All information and images are relevant and support the content	/10
-Project reflects your best effort over two weeks -Complete your project with care and attention -Revise, Edit, and Publish your Project by the deadline	/10
-Use proper grammar and punctuation -Use proper sentence and paragraph structure -Use transitions to go from one topic to the next	/10
Attach to your project a Reflection in writing or video -How did you go about working on your project? (Explain each step in detail) -What were the biggest challenges? -Would you do anything differently if you did it again? -What are most proud of? -What's the most important thing you learned from doing this?	/10
Total Points	**/100**

Appendix G

Final Project Choices - Eli



Circle one Final Project Type:

Adobe Spark Video	Board Game	Podcast Episode
Google Site	Google Slideshow	Google My Maps Virtual Tour
Musical Recording	Cookbook and Food (nut-free)	3-D Printed Model
Mosaic	Sculpture or Model	Drawing or Painting Series
Newspaper	Newscast	Cartoon with Storyboard
Short Story	Series of Poems	Community Service Project
Historical Fiction Journal	Design a solution to a problem in our community	Photography Collection

OR... Design Your Own: _____

I chose this Project Type because: _____

_____

_____

What materials and supplies will you need to complete this project?

_____

_____

_____

_____

Will you need any special help from teachers? If so, which teachers, and what kinds of help?

_____

_____

_____