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MAKERSPACES IN K–12 SCHOOLS

Six key tensions

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The ideas underlying making and makerspaces in educational contexts are not new—hands-on, studio-type classes in woodworking, autoshop, ceramics, home economics, and other forms of vocational, arts, or career and technical education have a long history in U.S. education and themselves draw on centuries of apprenticeship learning (Rose, 2014). In early childhood education, students' longstanding engagements in forms of play, crafting, and tinkering have prefigured many of the practices and orientations now being associated with making and makerspaces (Wohlwend & Peppler, 2015; Marsh et al., 2018). Scholars have suggested that these engagements with creative, semiotic meaning-making practices through play, arts exploration, and tinkering represent 'maker literacies' that offer rich opportunities for civic and cultural participation (e.g., Marsh, Arnseth & Kumpulainen, 2018).

The past decade has seen an interest in bringing these making practices from informal learning environments (e.g., community centers, libraries, Maker Faires, and afterschool programs) into more formal school contexts (Fields et al., 2018). Some of these efforts have foregrounded aspects of maker literacies oriented toward imaginative tinkering, play, and experiential learning in classrooms; others have been tied to more instrumental ends, like preparing students for work in STEM sectors; and still others have collapsed elements from both stances (see Nichols & Lui, 2019). Scholars have raised concerns that such conflations can paper over contradictions in the meanings and purposes of making. For example, Vossoughi, Hooper, and Escudé (2016) argue that current configurations of making that draw from the commercialized maker movement and its focus on economic and nation-building rationales—rather than indigenous and other community-grounded models of making, crafting, and learning (e.g., Barajas-López & Bang, 2018)—reflect white, male, upper-middle-class values and practices that continue to exclude and silence youth from non-dominant communities and delegitimize different forms of knowledge production and cultural expertise.

This chapter explores tensions about the purposes and definitions of making as these maker practices become more institutionalized in schools in the form of makerspaces—which often promise rich, inquiry-driven, technology-infused learning opportunities for young makers without necessarily grappling with these competing ideologies and emerging tensions. A number of scholars have offered suggestions for how we might address these tensions when designing more equity-focused making practices in makerspaces (e.g., Castek et al., 2019; Norris, 2014; Tucker-Raymond & Gravel, 2019). For example, Tan and Calabrese Barton (2018) suggest that educators consider making practices in light of systemic, structural oppressions and the role institutional and societal structures play in shaping how making and makerspaces function for youth. Others point to the need to diversify representations of making and makers and expand access to these spaces and different forms of participation within them, particularly for youth from marginalized communities and identities (e.g., Blikstein & Worsley, 2016, Fields et al., 2018). In earlier work we cautioned that "makerspaces should not be positioned as panaceas that can be inserted into classrooms as an autonomous fix for 'failing' schools and 'at risk' students" (Stornaiuolo & Nichols, 2018, p. 27). Other scholars are beginning to explore how equity-driven approaches to making must take into account people of all ages, especially younger children (e.g., Marsh et al., 2019).

In this chapter, we explore some of the tensions that emerge when maker practices are adopted in schools, drawing both on a review of the literature on school-based makerspaces as well as a longitudinal study of one school's development of different kinds makerspaces. We begin by offering a brief history of the role of making in education and then describe our five-year study of one urban high school's multiple makerspaces. We next outline six ideological and practical tensions that educators, researchers, and policy-makers should consider in creating and studying makerspaces in schools—access, (infra)structure, standardization, failure, collaboration, and logistics. We conclude with implications for future study and practice of school-based makerspaces.

A brief history of educational makerspaces

Before they were innovations for education, makerspaces were conceived as community hubs, replete with tools and materials for DIY crafting—an extension of computer clubs and hackerspaces that have surfaced, in diverse forms and locations, since the 1980s (Davies, 2017). The concept entered wide circulation in 2005 with the publication of *Make*, a hobbyist magazine providing how-to guides, product reviews, and profiles of 'makers' and their projects. Dale Dougherty, the magazine's founder, coined the term "The Maker Movement" to denote the community that began to form around the publication and its attendant network of international Maker Faire events (Dougherty, 2016). It was amid the proliferation of this "movement" that making began finding resonance among education researchers, policymakers, and practitioners. In 2014, the Obama administration hosted a White House Maker Faire and inaugurated a National Week of Making. At this event,

President Obama introduced his Nation of Makers initiative, which opened streams of funding for makerspaces in under-resourced schools and communities to help students become "makers of things, not just consumers of things" (White House, 2014). In the years since, school leaders and teachers in the U.S. have continued to cultivate such spaces, investing in resources for 3D printing, laser cutting, e-textiles, and robotics—or, generally working to increase opportunities for hands-on learning through imaginative tinkering and play (Kim et al., 2018). Similar practices have taken root around the world—from the UK and Singapore to Ghana and China—signaling a transnational interest in the possibilities making might hold for teaching and learning (Irie et al., 2019).

Part of making's broad appeal in education is that its underlying principles can be aligned with those of a range of stakeholders. As Dougherty (2016) suggests, the heart of making is not about tools or projects themselves, but about developing a "maker mindset"—an orientation to learning that celebrates playfulness, curiosity, self-direction, risk-taking, and resilience (p. 144). Importantly, these dispositions can be leveraged in service of very different educational outcomes. Policymakers, for example, have expressed enthusiasm for makerspaces because the "maker mindset" can be aligned with national goals for building human capital in innovative sectors, like STEM (Hsu et al., 2017). The Obama administration's Nation of Makers initiative, for instance, was closely tied to a federal Investing in Innovation program that saw K-12 education as a key building-block in national economic competitiveness (Honey & Kanter, 2013). Education researchers and practitioners, by contrast, are often drawn to making for other reasons: namely, its shared affinities with longer traditions of hands-on learning-by-doing and student-directed inquiry. This is evinced in the tendency for the making literature to trace the concept's genealogy through the history of progressive pedagogy, from Seymour Papert back to John Dewey (Martinez & Stager, 2013). Some scholars have cautioned that these competing purposes for making are, at times, conflated in publications like *Make* or the educational books that bear its imprint, which can lead to contradictions when making is folded into learning environments (Nichols & Lui, 2019). But it is also the pliability of the term that has allowed it to find uptake (and funding) in schools and community spaces that might otherwise be subject to cuts or austerity measures. Indeed, for multiple years, the New Media Consortium's Horizon report has consistently listed makerspaces as an "important development" for schools to consider (Freeman et al., 2017), citing their capacity to "cultivate environments where students take ownership of their education by doing and creating" (Johnson et al., 2015, p. 1).

To date, the inclusion of makerspaces in schools has been more speculative and experiential than empirically tested. Making has been championed as a resource for transforming schools—not just as a curricular add-on, but as a way to reimagine disciplinary learning altogether (Halverson & Sheridan, 2014)—yet until recently, much of the research on making has occurred in out-of-school contexts like museums, libraries, and community makerspaces (Bevan et al., 2015). Such work has been instrumental in demonstrating how makerspaces take different forms

(Sheridan et al., 2014) and can open opportunities for STEM-rich learning (Kafai, et al., 2014). They have also highlighted how such practices can challenge gendered access in STEM education (Buchholz et al., 2014) and develop "equitably consequential learning" for students from nondominant communities (Calabrese Barton et al., 2017). These efforts to trace the learning affordances of makerspaces often focus on the benefits of inquiry-based learning and hands-on engagement for promoting problem-solving, collaboration, and forms iterative learning that reframe 'failure' as an opportunity to learn from what does not (yet) work (e.g., Martin, 2015; Peppler, Halverson, & Kafai, 2016).

However, these exciting potentials remain under-explored as making is integrated into formal learning in K-12 schools. Within the nascent literature on school-based making, two lines of inquiry are emerging. One applies making as a lens for theorizing already-existing practices that occur in schools. Wohlwend and colleagues (2018), for example, suggest that forms of toyhacking, digital filmmaking, and remixing in early childhood education can be conceptualized as "maker literacies." The National Writing Project, similarly, now offers workshops that position writing as a form of making. Scholars working in this area have explored how makerspaces, particularly for young children, can blend digital and non-digital hands-on learning to draw on youth's funds of knowledge (Marsh et al., 2019). Such work considers how the language of making might offer new resources for understanding and expanding existing inquiry-oriented activities.

The other line of inquiry examines what happens as contemporary discourses and practices of making are introduced in school settings, from early childhood to high school (Kostakis et al., 2015; Marsh et al., 2018; Martin et al., 2018; Stornaiuolo et al. 2018). Within this orientation, scholars have noted that the alignment of makerspaces with the residual structures of formal schooling is not always easy to reconcile: when the competing purposes for educational making are grafted onto school systems with their own histories of inequity, frictions emerge—often with uneven consequences for students and teachers. Such concerns become especially critical as a growing research base is now highlighting how racial, gendered, and economic inequities are often reproduced in the places and practices of making (Nascimenta & Pólvora, 2016; Vossoughi et al., 2016). For this reason, amid the promises of the maker movement, there is a need for careful reflection about the tensions that surface at the intersection of makerspaces and K-12 schooling.

The case of the collaborative design school: embedding makerspaces in schools

We situate this chapter in the context of our five-year university–community partnership with the Collaborative Design School (CDS, a pseudonym), a non-selective, public, design-oriented high school in a large urban city on the East Coast of the U.S. The partnership was established in 2014, before the high school opened, through our ongoing conversations about the intersections of making and literacy with the principal, a dynamic local educator committed to technology-rich,

open-access educational opportunities for all students in the challenged urban district. To reflect the school's ideas about learning through the design process, the principal envisioned three interdisciplinary makerspaces that would support students in thinking about broad societal issues using different tools for taking action in the world. The three original makerspaces were focused on media arts (the Highlight lab), industrial arts (the Build lab), and community organizing (the Organize lab). In the school's first year (2014–2015), we collaborated to create a fourth makerspace (the Literacy lab) oriented specifically to literacy (we detail the process of co-construction in Stornaiuolo, Nichols, & Vasudevan, 2018). We argue here that studying a school experimenting with various kinds of makerspaces—rooted in ethnography, literacy, media, and industrial arts rather than just with traditional STEM disciplines—can offer an important opportunity to learn about how an ethos of making can be tied to various ideologies about learning. As Castek and colleagues (2019) have found, makerspaces are being realized in a multitude of ways that have different implications for realizing equity goals.

Across the five years, we studied how students and educators designed, shaped, and learned in and across these makerspaces—and how they functioned individually and collectively in the school—in a social design research study (Stornaiuolo & Nichols, 2018). As a social design research experiment (Gutiérrez, 2016), the study involved working alongside stakeholders to reorganize sociohistorical practices in ways that create more equitable outcomes for learners (Gutiérrez & Jurow, 2016). In this case, we worked alongside educators to iteratively integrate and study how the inquiry-driven, hands-on, culturally relevant projects in/across the makerspaces helped youth from nondominant communities see themselves as makers, authors, and designers of their futures. We studied how the media makerspace flourished from the beginning of the school, supporting students in developing familiarity with new technologies for digital media creation and the capacities to contribute to broader public conversations through their creations.

However, amid the successes of the media makerspace in that first year, the other two original makerspaces struggled to find a rhythm and place in the school and its individualized curriculum. The Organize lab, which supported students in connecting with local community and neighborhood groups, initially seemed more like a class than a lab—oriented to learning through online research rather than making and designing. Over the years, the Organize lab curriculum integrated more hands-on, collaborative activities as students engaged in ethnographic and activist inquiry in their own and nearby communities, solidifying its role within the broader school culture oriented to inquiry and equity. The Build lab, which looked most like what one would imagine a makerspace to be in its combination of power tools, electronics, and textiles, was closed by the principal after the first year due to staffing issues. The Literacy lab, developed as a kind of hybrid library-art studio-writing center to support students' literacy practices, has continued to both struggle and flourish as it became a student-run space without a dedicated teacher (Plummer et al., 2019; Stornaiuolo, Nichols, & Vasudevan, 2018). We studied how these four labs functioned in the broader school ecology over time,

particularly as they helped shape collaborative, outward-facing practices the school became known for in the district, and how the maker literacy practices in each space emerged and developed (often in different ways). We also traced the challenges facing the different makerspaces and stakeholders over the years, identifying key tensions that emerged in integrating them into the school's more formal structures.

In light of the ways makerspaces have begun to emerge at highly resourced, often private K–12 schools (Tan & Calabrese-Barton, 2018), it is important to note that CDS, like the district it is located within, serves primarily youth of color and students from socioeconomically under-resourced backgrounds. The school's focus on recognizing and cultivating their students as 'makers' was a deliberate effort to push back on the ways that youth of color and working-class students are rarely seen as makers and subject to narrow, deficit models of teaching and learning (Vossoughi et al., 2016). Indeed, a recent federally funded initiative to explore the future of making in education has identified the urgent need to engage in such critically turned making practices as instantiated by CDS, calling in their report for the need to center equity in all makerspace design, with special focus on addressing socio-political and economic inequities within these spaces (Castek et al., 2019). Our efforts to study how one critically attuned school designed and developed makerspaces represent an important contribution—not only in understanding the role makerspaces may play in more formal learning contexts but also the ways that makerspaces themselves can be used to create more equitable and just educational practices. To accomplish this goal, however, we argue that scholars, practitioners, and policy-makers need to grapple with persistent tensions that arise in relation to systemic oppressions and institutional structures that shape makerspace practices in schools (cf. Tan & Calabrese Barton, 2018).

Six central tensions to navigate with school-based makerspaces

We turn now to outline six tensions that emerge when making is folded into K–12 schools, based on a review of the literature and our longitudinal research with one maker high school. We begin with three tensions that are broader in scope—access, (infra)structure, and standardization—and that call into question the ideological coherence of makerspaces in K–12 spaces. The second set of tensions—failure, collaboration, and logistics—arises within the practices of a makerspace in its local context, pointing to the on-the-ground issues that must be continuously negotiated in the course of making activities. These six interlocking tensions, both global and local, present challenges that stakeholders must address if they wish to create equitable and transformative learning conditions for all students.

Access

In the current scholarship on makerspaces in education, issues of access are at the top of any list of challenges. These challenges around access identified in the

literature range from the lack of makerspaces in underserved communities to the lack of representation of young people of color, women, and younger children in STEM and broader maker discourses (Calabrese Barton et al., 2016; Marsh et al., 2018; Vossoughi et al., 2016). Other researchers point to tensions around access not just to these spaces but to the forms of participation within them, whether that involves the move from more trivial to more consequential projects (Blikstein & Worsley, 2016) or the difficulties of supporting youth's interest-driven practices when they do not have a choice about participating in a K–12 space (Fields et al., 2018).

Some of the tensions around access involve underlying assumptions about technology as the central driver of change, with power assumed to be residing in the spaces or the tools themselves—as if putting makerspaces into schools will transform educational possibilities in much the same way that some (wrongfully) assumed that putting computers into classrooms would (Martin, 2015). This tension around access is complicated by individual understandings of access (i.e., whether one can engage or not in the space or practices) that do not question assimilatory practices and oppressive institutional structures that continue to disadvantage historically marginalized groups and individuals (Barajas-López & Bang, 2018; Tan & Calabrese Barton, 2018). A broader perspective about access raises questions about the very purpose of integrating makerspaces within school contexts.

In tracing how tensions around access played out in CDS, we found that questions about the purpose of the makerspaces persisted across the five years of the study. These questions arose in the first year most forcefully, as district officials, parents, students, staff, and research team members all conceptualized the makerspaces differently. Some wondered how these spaces were distinct from 'regular' classes—a concern particularly at first as humanities teachers doubled as makerspace teachers in bare-bones rooms with few resources. Most people understood the purpose of the media makerspace, with its focus on digital communication technologies, but were less certain about the need for hands-on ethnography. Others found the industrial arts makerspace to be interesting in theory but loud and chaotic in practice. Parents and staff generally believed in the broader vision of including makerspaces, given the design focus of the school, but some questioned whether students had time to engage in these 'extra' interest-driven activities. We see these questions around the broader purpose of the makerspaces as a fundamental tension about access: what does it mean to participate in interest-driven, inquiry-oriented practices in an educational system that is supposed to prepare young people (particularly young people of color) to be successful in their college and career aspirations? Who should participate in these spaces and to what ends? This core tension was one continually negotiated across our time in the school.

(Infra)structure

The second tension we introduce here involves multiple ways that the structures of school condition makerspaces: including how infrastructures at the school and

district level support the functioning of makerspaces and how makerspaces are organized internally and within the school. Like any educational innovation, makerspaces do not just enter schools frictionlessly—even if there are ways that they ostensibly align with already existing pedagogies, they invariably bring new infrastructural arrangements that may not be easily reconciled with the residual infrastructures already at work in schools (e.g., physical spaces, class time, curricula) (Nichols, forthcoming). It may be tempting to read such tensions as a failure of outmoded school rituals to accommodate the dynamism of educational making; however, such a stance can overlook the important work that extant school infrastructures do for students. Eliminating familiar routines to create space for more open-ended making may actually undercut important infrastructures on which students depend. In other words, infrastructures of making and schooling are often agonistic, and efforts to build up one may subvert the other. As such, educators interested in merging the two will need to assess the interoperability of existing and new infrastructures—and to weigh who might be impacted by their internal contradictions. How do material, human, and procedural supports align or breakdown in practice? How do new infrastructures alter, threaten, or degrade already-existing infrastructures, advantaging those who are most poised to adapt to such circumstances, while making things more difficult for others? These questions point to decisions that must be made to structure the makerspace within the school system, decisions around staffing, open hours, youth activities in the space, and many other logistical details (addressed below) that structure the ways makerspaces 'fit' within the broader school ecology (Salisbury & Nichols, 2020).

At CDS, tensions around (infra)structure abounded. Even in a school with a philosophy directly aligned with the open-ended, inquiry, design-oriented nature of makerspaces, people had a challenging time creating structures that worked within the systems of district, state, and federal schooling policies and expectations. For example, the school needed to address who would staff the spaces when facing a shoestring operating budget: how students would access the space (for credit? With a pass? During a class?); how work would be evaluated and recorded in the school's competency system and in relation to the district and state grading systems; how work in the space overlapped (or should overlap) with other classes; how to help students build expertise (and navigate those students who did not want to participate); and myriad other concerns.

One way of addressing this tension initially involved the research team filling in infrastructural gaps: being present in the spaces to lend a helping hand, writing grants with stakeholders for equipment, working as thought partners to solve dilemmas with students and staff, taking the lead on building out the Literacy lab. Other ways stakeholders addressed this tension involved allocating resources creatively—closing the Build lab, hiring lab teachers who could teach other subjects as needed, collaborating on disciplinary-focused projects that would satisfy district graduation requirements. Yet infrastructure challenges mounted: Should students be required to take classes in both labs each year, and if so, for a quarter or semester? How should the curriculum change each year for returning students to allow

for deepening expertise? Should classes remain mixed-grade levels or focus in on particular grade, topical, or expertise levels? How should classroom teachers connect their work with the curriculum in the makerspaces? These questions were regularly debated by the staff each year, illustrating that tensions often emerged, shifted, and resurfaced over time and in relation to other schooling systems and structures.

Standardization

Halverson and Sheridan (2014) explore tensions around standardization quashing emergence and creativity. They argue that people need access not just to school knowledge but discourses of power. Informal making and formal schooling can sometimes have different orientations. For example, where school is often oriented toward disciplinary practices, making often emphasizes transdisciplinary projects. While schools are often organized around disciplinary knowledge, making is often championed as being discipline-agnostic. These are competing ends that can make it difficult to understand what successful making is or looks like—if a student completes an impressive project that is unrelated to disciplinary content being covered, is this still successful? Or if a student demonstrates competency in a given standard, but the project they make is not aesthetically pleasing, is this still successful? A tension remains in how making is related to the content of education—and whether its practices are amenable to the forms of learning objectives that mediate instruction and practice in schools. While it may be tempting to suggest that disciplinary boundaries are arbitrary, and learning should be more transdisciplinary than standardized, this can overlook the fact that transdisciplinarity can only exist as a desirable or generative category to those who have enough understanding of disciplinary knowledge to recognize how it is being combined or reworked. This raises a larger question for educators, then, of what the purpose of making is: Is the purpose to make projects? Is it making projects that demand some consolidation of disciplinary knowledge? Is it making projects that impact the world? How one answers this question could have strong bearing on what educational making will look like in these spaces.

At CDS, this tension surfaced most clearly as students' projects in the school makerspaces were being assessed. At the behest of teachers who were hoping to encourage interdisciplinary inquiry, students often used the school makerspaces to complete projects for their core, content-area classes. For instance, in a humanities unit centered on "American Mythology," many students used the media makerspaces to create videos, podcasts, photo essays, and infographics that explored the mythos of "the American Dream" and the ways opportunity has been unevenly distributed in U.S. history. However, after completing such projects, some students were surprised to learn that they had not received full credit for their work: while the media artifacts they produced were creative, technically proficient, and intellectually rigorous, they did not necessarily meet particular disciplinary standard that teachers were expecting students to demonstrate in that unit (e.g., particular forms of

outlining, argumentation, or historical thinking). In other words, exemplary making practices did not necessarily align with the particular demands of formal, disciplinary learning; and, likewise, rich, disciplinary learning was not always easily translatable into projects that allowed for hands-on making. A persistent challenge that educators faced, then, was how to reconcile this tension in the ways that they designed assignments, explained expectations, and evaluated student work.

Failure

In maker discourses, failure is to be expected and celebrated, a crucial part of the tinkering, iterating, and designing process (Gabrielson, 2013; Martin, 2015). Indeed, scholars regularly tout the benefits of failure as a productive element of all learning and an avenue to developing adaptive expertise (Blikstein, 2013; Kapur, 2008), arguing that the negative definitions of failure promulgated in schools have overshadowed the generative, process-oriented aspects celebrated in makerspaces (Litts & Ramirez, 2014). When makerspaces move to formal school settings, however, the tensions around what constitutes 'productive' failure are heightened (Stornaiuolo & Nichols, 2018), particularly for students of color and working-class youth who experience the repercussions of failure in more consequential and historically conditioned ways (Vossoughi & Bevan, 2014). With schools discouraging and penalizing failure, particularly for youth of color already subject to deficit framing and 'at risk' labels (Gadsden et al., 2009), it seems disingenuous at best and harmful at worst to advise that students 'fail fast and fail often' or understand failing 'as the new winning' (Martin, 2015). This tension around iteration and failure must be constantly navigated in school-based makerspaces.

The ethos of CDS, with its emphasis on design and use of standards-based grading, lent itself to a generous reading of 'failure' as a form of learning—yet the tensions around failure still emerged regularly. One of the central challenges at CDS involved evaluating process vs. product in the labs: students were encouraged to imagine, build, try, and fail as many times as they needed along the way to a finished project, but students knew that only the final project counted for their grade. In the media space, for example, students engaged in a data literacy project in which they collected personal data and created mixed media representations of the data. For some students, the open-ended nature of the design process was liberating, as they iterated on different aspects of the data collection, analysis, and design process; for others, the steps seemed tedious, and they asked the teacher exactly how to skip directly to making the final representation 'correctly' for a good grade. These students did not want to (or feel comfortable with) trying and failing many times—they wanted more clear-cut directions about how to be successful in making a product that would ultimately be evaluated with a grade. The reality for many students was that failure was not creative, aspirational, or opportunity-laden: failure involved vulnerability, judgment, and stigma (that many had deep experience with in previous schooling).

Collaboration

Another tension involves the ways that makerspaces prioritize and encourage collaboration, whether that involves activity with peers, between expert and novice makerspace users, or in adult–youth pairings. Ching and Kafai (2008) have found that peer pedagogy in makerspaces offers young people the support of their peers in groups, with students providing important forms of apprenticeship and camaraderie in the learning process. Fields and colleagues (2018) expanded on the concept of peer pedagogy for school-based makerspaces, finding that students, particularly those with developing expertise, played an important role in supporting the lone teacher; students also reported that those peer-based collaborative practices fostered greater enjoyment, friendships, and engagement in the space. While collaboration is a central aspect of makerspaces, schools generally value independent work and often issue individual grades that can make it challenging to assign and assess collaborative making activities. Further, there is often only one teacher assigned to a makerspace, creating difficulties in fostering a culture of peer collaboration and sustaining adult–youth mentoring around individual student inquiries. Any school makerspace will have to negotiate tensions that arise around the role of collaborative work in and beyond the space, how it will be counted in the other grading systems and structures, and whether such work will be encouraged and nurtured.

In the CDS makerspaces, peer pedagogy flourished—students who were experienced or savvy in an area often served as an expert, formally or informally, in guiding novices to use a camera, conduct an interview, measure an angle, or edit a piece of media. The teachers encouraged those collaborations both informally (e.g., asking a student to consult with someone who had already finished) and more formally (e.g., offering students the opportunity to take the course a second time for credit while serving as a teaching assistant). Other kinds of collaborations involved projects shared between makerspaces, such as a documentary project investigating the history of the school neighborhood that involved both the community organizing makerspace (conducting interviews and engaging in archival research) and the media makerspace (documenting all of the interviews and creating films, podcasts, and promotional materials to share). While the makerspace teachers grappled with how to assign individual grades to group projects, the more challenging forms of collaboration involved projects that spanned disciplinary classes (e.g., a documentary film created for a humanities assignment) or that involved independent projects students pursued in a lab (e.g., a literary arts magazine created by students). Teachers were not sure how to navigate students' time for collaborative activities (should students be able to visit the necessary lab during class time or only during free periods like lunch?), how to evaluate the project (should the humanities teacher assess the quality of the film or only the content?), or how to negotiate the collaborative elements with other teachers (should teachers create or assess assignments together, and when/how should they do so given constraints of time and curricula?). These tensions around collaboration were continually being negotiated over the five years.

Logistics

Logistical challenges, while seemingly mundane in nature, are often some of the most pressing to navigate for stakeholders. One question around logistics that is common with makerspaces involves decisions about whether these should involve formal classes or be drop-in spaces where students can go to work on projects. Kim et al. (2018) suggest that there should be open hours so that students can make use of the makerspace facility, even when it is not mandated for course participation. However, there are challenges that come along with this: for school contexts that are already under-staffed, or who have already seen cuts to libraries and other programs, this means staffing could be an issue (whereas well-resourced districts would not face this same challenge). And while staff may be willing to supervise, the question of how to find someone trained in the STEAM practices who can foster an inquiry-based and equity-oriented space represents an ongoing challenge. When makerspaces have open hours (like libraries or art studios do), the spaces themselves can sit apart from daily learning routines, with educators needing to find time to bring their classes to the space or integrate making practices into their curricula. Students too need to navigate rules about how and when they can visit on their own time to work on projects (e.g., lunch, recess). When students and educators are already pressed for time in covering academic requirements, these time constraints have an impact on cultivating the kinds of tinkering, exploring, and inquiry-based activities makerspaces are known for. For schools that have adopted more formal classes in the makerspaces, logistics like time and access need to be negotiated in different ways, such as fitting those classes into students' often overburdened schedules or ensuring that all students understand the opportunities and activities within the space. Questions about who owns the materials or can have access to these spaces also arise. These logistical tensions seem routine perhaps, but more than any of the other tensions can represent some of the most persistent challenges in using the space.

One of the biggest logistical challenges for the CDS makerspaces was figuring out who could and should access the space and when. Since the principal hired expert teachers in each of the two formal makerspaces, these spaces functioned as hubs within the school. In fact, they were so popular that students often just showed up when they should have been elsewhere. When the principal moved all of the makerspaces (including the literacy one—without a core teacher) to a separate floor as part of a broader reorganization, students had to make a deliberate journey two floors above their disciplinary classrooms. The move did curtail most of the 'showing up' issue that had emerged, but the lack of foot traffic meant that some students were not aware of the lab spaces until they were speci-fically assigned there in their second year. For first-year students, the spaces were no longer part of the ethos and core fabric of the school in the same way, and students felt less connected to the making/tinkering opportunities, seeing the labs as just another class they were required to take (a non–elective elective, if you will). These logistical issues, clearly, had a broad impact on the learning culture of the

school and students' experiences in the spaces themselves. Each year, the CDS staff worked to address those logistical issues—holding showcase weeks, integrating the labs into the first-year experience, creating more opportunities for collaboration—but these were constantly being negotiated.

Implications for future practice

The tensions we highlight above do not lend themselves to simple solutions. Indeed, many hinge on perennial questions about the purpose, form, and content of public education itself. We delineate them here because of, not despite, their intractability: any serious effort to integrate makerspaces into K-12 schools must involve meaningful deliberation and reflection about the underlying frictions that animate educational making. Crucially, negotiating such tensions will look different depending on a school's context and purposes for making as well as the ages of the students. A well-resourced program, for example, may have the benefit of time, space, and equipment to create and sustain a makerspace; but it may have more difficulty seeing and addressing the ways its efforts to do so could be bound up with wider systems of domination. By contrast, in under-resourced programs, the steady fight for funding or access to educational making may, at times, make it harder to critique how inequities often persist in and through efforts to expand access. In other words, while the research on making and makerspaces over-whelmingly points toward their promising possibilities for education, realizing this potential demands vigilant interrogation of their purpose and function in local contexts for learning, and the residual tensions that surface as they are grafted onto formal school environments.

As we have suggested, makerspaces are not an autonomous fix for systemic problems in schools. They are one resource, in a wide repertoire of possibilities, for reconfiguring certain educational arrangements that have historically reinforced such issues. Addressing these arrangements involves more than adding a makerspace to a school; it means engaging in the material work of reconciling the tensions between making and schooling. This includes the reflexive labor needed to con-sider how racial, gendered, and economic formations of difference might be reproduced, even through practices and reform efforts that ostensibly champion access and diversity. It involves the pedagogical labor necessary for addressing asymmetries in the purposes for making, and orienting instructional supports and resources so that all students can flourish. And it includes the administrative labor required not only to enable such spaces to function, but also to allow them to grow and evolve over time in response to the needs of those who use it.

Foregrounding the labor involved in addressing the tensions of making and schooling helps elucidate some important implications for educational practice. For educators, it is at the level of the classrooms that much of this labor is conducted; and it is here that the tensions we have highlighted will be most pronounced. As such, there is need for reflection and planning that is explicitly attuned to these frictions—and a need for practitioner perspectives on the successes and challenges

associated with addressing them. Researchers can play an important role in this regard, studying how educators and administrators are engaging in the labor of reconciling these frictions in local sites, or examining emergent patterns across contexts. There are also opportunities in this work to examine a wider range of relevant stakeholders who are not always included in studies of educational making—parents and communities, for example, or the influence of private philanthropy and commercial interests in school makerspaces. While such research can help synthesize resources for practice, there is also a need for policy interventions that do more than allocate funds for makerspaces, but provide the resources educators need to engage in the forms of labor that make them generative learning environments (including issues of sustainability over the longer term).

Taken together, these perspectives point toward an emerging agenda for research and practice as making and makerspaces continue to find resonance in schools. There is a rich literature that has demonstrated the transformative possibilities that makerspaces might hold for formal learning. Looking ahead, there is vital work to be done to understand how these possibilities might be realized in ways that promote just and equitable learning for all students.

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