Innovation from Below: Infrastructure, Design, and Equity in Literacy Classroom Makerspaces

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A growing research base has examined the possibilities of makerspaces in education; however, there has been little exploration of how such innovations are folded into formal school structures, like English language arts classrooms. This article addresses this by following the formation of literacy classroom makerspaces in the Innovation School—an urban public high school organized around principles of making. Using ethnographic research conducted over the school's first two years, it traces how teachers integrated making into literacy instruction and how the contours of classrooms were reshaped by making's ideals and assumptions. In particular, it focuses on resulting shifts in the infrastructures of literacy education—the often-invisible mechanisms that support, sustain or undermine reading and writing in classrooms. Findings show how the interoperability of these literacy infrastructures with those of making produced frictions that had uneven consequences for students, at times reproducing forms of deficitization that making education is often purported to ameliorate. These outcomes elucidate possibilities and challenges for educational equity when literacy learning is refashioned in the image of innovations like making. They are also instructive for understanding how educators might imagine "innovation" otherwise, wresting it from experts and entrepreneurs and relocating it in the lived dynamics of classrooms.

Education is no stranger to innovation. At an early meeting of the American Institute of Instruction—the first US teaching organization—Hubbard Winslow convened the gathering, saying, "Innovation seems to be the prevailing spirit of our age." That was in 1834—though his words are similar to those of today's reformers and entrepreneurs. In the years separating us from Winslow, educators have worked steadily to study and harness "innovation" in education: from researching the diffusion of pedagogical innovations (Mort & Cornell, 1941) to establishing district "Innovation Offices" (Resnik, 1970) to leveraging design-based methods for sustaining innovation in schools (Bereiter, 2002). Even in the pages of *Research in the Teaching of English*, editors have reflected on the "continuities and innovations" shaping literacy research over time (Dressman, McCarthey, & Prior, 2012). Few features, it seems, are more persistent in education than the field's reflexive interest in its capacity to innovate—to continue or break from tradition, to change or be changed.

Recently, *making* has emerged among education's latest innovations, finding uptake in research, policy, and practice—including those associated with literacy learning. The term resists precise definitions, but *making* refers generally to practices related to do-it-yourself designing, remixing, and building using physical and digital tools. Entering wide circulation in 2005 with the launch of *Make* magazine, the concept accelerated under the Obama-era Nation of Makers initiative, which introduced a National Week of Making and opened funding streams for "makerspaces" in underserved communities. Since then, school leaders have continued investing in such spaces, equipping students with resources for 3D printing, laser cutting, and robotics—or generally increasing opportunities for hands-on learning through imaginative tinkering and play (Kim, Edouard, Alderfer, & Smith, 2018). These practices, advocates argue, hold transformational possibilities for schools, not just as a curricular add-on but as a way to reimagine disciplinary learning altogether (Halverson & Sheridan, 2014). In literacy studies, for example, scholars have examined making in relation to other forms of multimodal composition (Stornaiuolo & Nichols, 2018), and the National Writing Project (2013) has offered workshops that conceptualize "writing as making."

Despite this mounting interest, we know little about how making is integrated in actual literacy classrooms. Though making entered policy as an innovation for reshaping schools, research has centered on out-of-school contexts like museums, libraries, and community makerspaces (Bevan, Gutwill, Petrich, & Wilkinson, 2015). When studies have been grounded in schools, they have been located in STEM-oriented electives, rather than content-area courses not expressly affiliated with STEM (Martin, Dixon, & Betser, 2018). Most have also limited the scope of their inquiry to individual projects—not the longitudinal inflections making brings to curriculum and instruction over time (Kafai, Fields, & Searle, 2014). Existing research, then, has been instrumental in mapping the learning opportunities makerspaces afford, but there is need for exploration of what unfolds when such innovations are grafted onto formal school structures. For literacy educators, pressing questions remain: What happens when innovations, like making, come to frame school-based literacy learning? How do their associated practices remake the work of literacy instruction? What opportunities and obstacles might this yield for educational equity?

This article attends to these questions by examining the formation of literacy classroom makerspaces in The Innovation School (a pseudonym)—an urban public high school organized around principles of making. Using research conducted over the school's first two years of operation, I explore how teachers integrated making into literacy instruction, and how the contours of classrooms were reshaped by the innovation's ideals and assumptions. In particular, I focus on resulting shifts in the *infrastructures* of literacy education—the often-invisible mechanisms that support, sustain, or undermine reading and writing in classrooms. Findings examine how the interoperability of these literacy infrastructures with those of making produced frictions that had uneven consequences for students, at times reproducing forms of deficitization that making education is purported to address. These outcomes

elucidate possibilities and challenges for educational equity as literacy learning is refashioned in the image of innovations like making. Importantly, I argue, these outcomes are also instructive for understanding how educators might imagine "innovation" otherwise, wresting it from experts and entrepreneurs and relocating it in the lived dynamics of classrooms.

Literacy in the Making: Process, Structure, Content

Literacy education also shares an entangled history with innovation. In the 1970s, educators called for innovations in literacy pedagogy that centered instruction on "process" rather than "product" (Murray, 1972). In contrast with skill-oriented approaches to teaching writing, process-advocates emphasized the iterative cycles of planning, drafting, and revising that constitute written compositions (Flower & Hayes, 1981). This orientation highlighted the significance of audience and purpose in writing development, and opened conversations about how curricula might give students more control over what they read and write (Graves, 1983). Such discussions prompted subsequent innovations—notably, the integration of reading/writing workshops into literacy classroom structures (Atwell, 1987). These spaces decentered teacher-led instruction, offering students time and space for independent literacy projects and personalizing support through mini-lessons and conferences (Graham & Perin, 2007). While there is variation in how workshops have been incorporated in schools, their reach, as an innovation, is widespread (Cutler & Graham, 2008). Each year, the National Writing Project continues to provide professional development using principles of process-writing and workshops (Whitney & Friedrich, 2013), and commercial curricula rooted in these models are widely used in districts and schools (Calkins, 2008).

Innovation in literacy also extends to instructional content. For decades, educators have argued for more expansive understandings of literacy—those that include the full range of semiotic modes that underwrite composing and interpretive processes (e.g., speech, writing, gesture, image; Jewitt, 2008; New London Group, 1996; Rowsell, 2013). As Kress (1999) argues, this orientation is "a linguistic, conceptual, and cultural innovation" (p. 132) that redefines the meaning and scope of literacy learning. In recent years, such perspectives have not only reshaped national policies (Australian Curriculum, Assessment and Reporting Authority, 2012), but also opened literacy research to forms of meaning-making that have not historically been recognized in schools: from digital storytelling (Hull & Katz, 2006) and spoken-word poetry (Kinloch, 2005), to comics (Low, 2017) and community activism (Campano, Ghiso, Yee, & Pantoja, 2013). These developments have inspired inquiry into how an expanded repertoire of semiotic practice might inform disciplinary literacy learning (Moje, 2009), and have motivated new research trajectories examining the imbrication of literacy with embodiment (Leander & Boldt, 2013), affect (Ehret & Hollett, 2014), and mobility (Stornaiuolo, Smith, & Phillips, 2017).

These innovations in the process, structure, and content of literacy education help clarify how making—an innovation conventionally associated with STEM

(Honey & Kanter, 2013)—has found resonance in literacy instruction. Making shares, with many literacy educators, an orientation toward process—foregrounding iterative cycles of prototyping that lead to deliverable products (Thomas, 2014). Makerspaces, likewise, share structural similarities with reading/writing workshops: both tend to be decentralized—organized into zones for individual or collaborative activities that students move between as self-directed projects demand (Stornaiuolo, Nichols, & Vasudevan, 2018). Finally, making's focus on aesthetic design aligns with pedagogies that extend the content of literacy beyond alphabetic text. Indeed, design has been central in theorizations of *multiliteracies* (New London Group, 1996), and scholars continue to study its interrelations with literacy practice (Sheridan & Rowsell, 2010). Given these intersections, it not surprising that many find generative alignments between literacy and making. This is evinced not only in the National Writing Project's (2013) "writing as making" workshops, but also in the growing literature conceptualizing *maker literacies* as a frame for research and practice (Marsh, Arnseth, & Kumpulainen, 2018).

Remaking Literacy: Innovation and (In)equity

Amid these convergences, however, questions remain about potential incongruities between literacy and making, and what these might mean for practice. Sociocultural literacy studies have long argued that innovations in pedagogy (e.g., new policies, technologies, or methods) are laden with assumptions that remake the meanings, purposes, and practices of reading and writing (Street, 1995). Crucially, this can have implications for educational equity. The remaking of writing during the process movement, for example, de-emphasized skill-oriented instruction, but it also produced pedagogies that sometimes failed to make explicit the raced, classed, and gendered expectations for normatively "effective" composition (Delpit, 1988). Workshop structures, likewise, have allowed students to bring their identities to bear in classrooms; however, they can also incentivize students to perform vulnerability or resilience in ways that leave them feeling exposed (Lensmire, 2000). Even expanded conceptions of literacy—those that encourage multimodal resources for making and interpreting meaning—can reproduce norms for ranking and sorting students if they are not accompanied by critical reevaluation of the classroom structures in which they operate (Campano, Nichols, & Player, 2020). Put simply, innovations are never add-ons to existing practice; they actively reshape it—often with unanticipated consequences.

This perspective becomes salient with regard to making, as scholars are beginning to interrogate the concept's underlying assumptions. Some note making's ambiguous place in the military-industrial-academic complex, as the maker movement has been substantially underwritten by federal defense spending (Vossoughi & Vakil, 2018). Nichols and Lui (2019), likewise, show how making advocates often exploit the slippery language of "innovation" to conflate experiential learning with more instrumental educational outcomes, like developing human capital in STEM fields or cultivating private entrepreneurship. Such tensions are only further compounded as they are mapped onto formal educational spaces. Though the making

concept's emphasis on self-directed learning is often positioned as democratizing (Blikstein, 2013), a growing literature shows that existing social strata persist in places and practices of educational making (Calabrese Barton & Tan, 2018; Vossoughi, Hooper, & Escudé, 2016). Nascimento and Pólvora (2018), for instance, demonstrate how narratives of empowerment and social transformation proliferate in makerspaces, yet their material outcomes rarely engage the conditions that produce marginalization or systemic injustice. Such incongruities are especially concerning as making is increasingly introduced in schools and communities that have, themselves, been conditioned by these same systems of domination.

There is need, then, to examine the interplay between literacy and innovations like making—not just their synergies, but their discontinuities and contradictions. While both involve design and production, for example, it is not evident that their purposes for each are aligned. As the New London Group (1996) cautions, such terms are easily co-opted for competing ends: "Innovation," they warn, "may fit well with a pedagogy that views language and other modes of representation as dynamic"; however, it can also be used to reinforce market-driven reforms that are incompatible with meaningful success for all (p. 67). For literacy educators especially, there is reason to be wary of such conflations. While making's spread into literacy studies can be viewed as an inroad for interdisciplinary learning, it can also be seen as part of a wider encroachment of STEM into other disciplines. Just as scholars in the 1990s recognized an emerging "new work order" reorienting literacy toward the demands of global capitalism (Gee, Hull, & Lankshear, 1996), we can find in the present a similar realignment of the humanities toward the concerns and methods of resource-rich STEM fields—from the rise of "digital humanities" (Lynch, 2015) and coding-as-literacy initiatives (Vee, 2013), to the influence of techno-capitalism in defining twenty-first-century literacies (Williamson, 2016). In this context, examining how innovations like making inflect literacy education becomes crucial, not just for understanding how the contours of the field are shifting, but also for making legible the implications of these shifts for educational equity.

Innovation from Below

I examine these relations here using a theoretical orientation I call *innovation from below. Innovation* is a nebulous buzzword in education. At times, it signals policies for bolstering economic growth through cultivation of human capital in "innovative" sectors (National Economic Council, Council of Economic Advisers, & Office of Science and Technology Policy, 2011). At others, *innovation* refers to novel technologies and strategies intended either to optimize internal processes of schooling, or to help education keep pace with external demands of a changing world (Selwyn, 2016). In practice, these competing purposes often blur together. Making, for instance, is regularly invoked as both a means to develop STEM labor and a resource for student-driven inquiry (Nichols & Lui, 2019). Such contradictions might tempt scholars to avoid the term *innovation* altogether. Doing so, however, elides the work the concept does for those who use it, and those who

bear its consequences. Innovation from below, then, aims to take innovation seriously by examining the situated meanings, uses, and impacts the concept carries into educational contexts. It considers its subject *from below* by attending both to the underlying infrastructures that animate and extend from innovations, and to their downstream implications for educational equity.

This orientation draws from science and technology studies (STS; Dear & Jasanoff, 2010)—a field interested in the contingent processes through which innovations are constructed and applied. As Latour (1987) argues, innovations that appear "ready-made" are actually held together by precarious constellations of materials, procedures, and institutions that grant them legitimacy and facilitate their spread. Exploring such constellations is a focus of the STS subfield of *infrastructure studies* (Edwards, Jackson, Bowker, & Williams, 2009), which works to surface the interdependent substrates that support, sustain, or undermine innovations. While early contributions to this domain centered on large sociotechnical systems like electric power grids (Hughes, 1983), recent studies have interrogated the mutual conditioning of infrastructures and human activities (Russell & Vinsel, 2018). Susan Leigh Star (1999), for example, describes how an innovation like a city water system is, at once, a physical infrastructure designed and maintained by urban planners and engineers, yet also a working infrastructure for other organizational practices—from domestic hygiene and commercial services to regional conservation initiatives. From this perspective, infrastructures are characterized by relationality—both to the practices they delimit or make possible, and to the other social arrangements in which they are embedded. In the context of this study, making may arrive in literacy classrooms as a ready-made innovation—even one ostensibly aligned with established literacy pedagogies—yet, it invariably brings new infrastructural arrangements that may not be easily reconciled with the residual infrastructures already at work in schools (e.g., standards, curricula). Innovation from below, then, extends educational research on innovations' manifestations in classroom practices (Cuban, 1986) to include the sociomaterial infrastructures whose alignments and frictions condition such outcomes.

Crucially, studying innovation from below also means attending to the consequences of innovations and their implications for equity. Feminist and postcolonial STS scholars have long researched history and science *from below* to unearth the subjugated knowledges and experiences papered over as dominant innovations are tested and scaled (Harding, 2008). Cowan's (1984) history of "time-saving" household devices, for example, shows how these innovations compounded expectations for domestic productivity while further gendering unpaid labor in the home. Arnold (1993), likewise, traces histories of colonial medicine in India to show how innovations in Western epidemiology exploited the knowledge and bodies of indigenous communities—violence erased from Whiggish accounts of medical progress under empire. The history of education, similarly, brims with innovative reforms and strategies—many advanced under the auspices of racial and economic equality—that have reproduced systems of white heteropatriarchy and imperial underdevelopment (Delpit, 2006; Rodney, 1972). In light of this

history, studying innovation from below means foregrounding issues of equity in analysis, rather than weighing them against an innovation's potential upside in a cruel cost-benefit calculus. This stance builds on literacy scholarship that calls for shifts in the location from which innovation is theorized (Ghiso, Campano, & Simon, 2013), attending to both the material outcomes wrought by innovation, and the ways the concept might be imagined otherwise.

Methods

Context and Participants

This study of innovation from below draws from immersive ethnography (Heath & Street, 2008) conducted in a longitudinal partnership between a research university in the US Northeast and the Innovation School, an urban public high school organized around principles of making. The school opened in 2014 at a transitional moment for its district. After budget cuts led to the shuttering of 30 neighborhood schools, administrators faced public backlash, with students, parents, and teachers demanding accessible alternatives to the private and charter programs expanding across the city. In a response journalists termed "The Innovation Gamble," the district announced it would open three new "innovation" schools that would bring technology-driven, project-based learning to students who might be excluded from similar programs due to income, geography, enrollment caps, or past academic performance. When the Innovation School opened, then, its demographics were similar to those of nearby neighborhood schools: the population was 80% African American and 15% Latinx, and all students received free lunch. The teachers and principal, similarly, came to the school from neighborhood programs. For them, as for the students, the Innovation School's focus on making offered a promising alternative to the regimentation unfolding elsewhere.

The Innovation School was structured around three makerspaces focused on media production, community organizing, and industrial arts. These were both stand-alone classes and spaces where students could develop projects for their content-area courses—humanities, science, and math. Assessment in the school was competency-based, meaning credits could be earned both within and between classes: for example, a student who devised a project in the industrial arts makerspace that required them to calculate volume could earn geometry competencies for doing so. But how this integrating of making and content-area learning would occur in practice was unclear—and it became the central inquiry of the university-school partnership. The spring before the school opened, the research team met with Ben, the founding principal, and agreed to document the school's efforts to implement its innovative, making-oriented curriculum. Researchers would trace shifts in teaching and learning over time and report emergent findings to teachers, who could (if they wished) use those insights in future planning. The study enrolled educators, as well as 45 students from the school's first two cohorts (a quarter of each class) to participate in periodic interviews that would allow the team to follow their trajectories in the school over time.

Researcher Role and Positionality

The role of a researcher in a university-school partnership is rarely singular—often occurring along a continuum of insider perspectives, collaborations between insiders and outsiders, and outsider perspectives that examine insiders' practices (Herr & Anderson, 2005). In long-term partnerships, researchers may occupy each of these roles—sometimes concurrently—in the ongoing ethical negotiations of the inquiry (Campano, Ghiso, & Welch, 2015). This was true as I managed the Innovation School research partnership. Sometimes I was a participant observer, sometimes a sounding board for instructional planning, sometimes a co-instructor. Far from compromising some chimeric sense of objectivity, these shifting roles allowed me to foster relationships with teachers and students, and to view the school model from varied vantage points—which provided an invaluable backdrop for contextualizing my research in the humanities classrooms.

But more than my institutional role required negotiations. As a white cis man working with students of color, my positionality was a source of ongoing reflection. Even the content of the study was inflected by these relations: universities have long propagated "innovative" reforms that underdevelop neighborhoods and entrench racial and economic stratification (Countryman, 2006). As I document elsewhere, this very district's earliest foray into "innovative" reform—opening an Innovation Office in 1967—involved a partnership with my home-university that initiated a racist urban renewal agenda whose impacts still resonate in the present-day school closures that prompted the Innovation School's opening (Maton & Nichols, 2018). Thus, my work demanded continual examination of my place in the "matrix of domination" (Collins, 1990) that allows injustices, educational and otherwise, to persist. This means acknowledging that my position and privileges remain implicated in the empirical record. And because my research has been supported by foundations rightly concerned with innovation's role in the relief or reproduction of inequality, it also means recognizing that I capitalize on the circumstances of those for whom innovation is not a research topic but a last resort in an education system that has gutted the commons to serve private accumulation. Naming these injustices does not absolve me of my place within them, but it acknowledges frictions that I have interrogated throughout my involvement with the project—through personal reflection, individual memos, and conversations with fellow researchers and school partners.

Data Collection

Data were generated in the Innovation School's humanities classrooms between 2014 and 2016, the first two years of the partnership. During this period, I visited the school weekly, dividing time between the stand-alone makerspaces and humanities classes. The latter became central to the study in Year 2, as literacy classrooms were refashioned into makerspaces. I documented my participation with teachers and students through field notes and memos; audio recordings of classroom activities, faculty meetings, and teachers' collaborative lesson-planning sessions; and photographs of physical artifacts, including student work and teacher-generated materials. I also recorded interviews with teachers and students enrolled in the study—these

included informal conversations about in-process projects and more comprehensive interviews at the close of each school year. These latter interviews ranged from 30 to 90 minutes and included reflections on the humanities classrooms as a whole, successes and challenges in particular units, and relations between the course and other parts of the school's innovative model (see Appendix for data sources).

Data Analysis

These sources were triangulated to map the infrastructures and outcomes of innovation as literacy classrooms were transformed into makerspaces. I used "whole-to-part" analysis (Erickson, 2004) to reduce and organize data into provisional categories. This involved rereading the data set, asking, what is going on in the planning and practice of literacy education? Through this process, I identified two phases in the configuration of literacy instruction, each corresponding with a different school year—an unsurprising delineation, as most substantive pedagogical shifts occurred between years, during summer planning. I clustered data associated with each phase and used a combination of theoretical and emergent coding (Bogdan & Biklen, 2007) to identify forms of infrastructure that helped organize literacy instruction each year. Four such infrastructural categories emerged: (1) *spatial*, which refers to the physical configurations of classrooms; (2) *textual*, which refers to the encoding of course content and instructional support into textual artifacts; (3) *human*, which refers to the work of human instructors and peers; and (4) *managerial*, which refers to administrative techniques that organized curricular and classroom content (see Table 1).

Importantly, the substance of these infrastructures is not new. Each could be understood, for example, as a resource for pedagogical *scaffolding*—a concept well-rehearsed in educational literature (Pea, 2004). Indeed, literacy scholars have long explored how spatial environments support varied engagements with

Table 1. Analytic Chart of Classroom Infrastructures

Infrastructure	Definition/Function	Examples
Spatial Infrastructure	Configuration of the physical classroom environment	Arrangement of seating and furniture; delineation of classroom spaces and their purposes; movement patterns
Textual Infrastructure	Encoding of course content and instructional support into textual artifacts	Unit guides, assignment/project overviews, written instructions, audiovisual instructional materials, worksheets, rubrics, textbooks
Human Infrastructure	Roles and relations of human instructors and peers	Direct instruction, whole-class discussion, mini-lessons, peer collaborations, teacher conferences
Managerial Infrastructure	Administrative techniques for organizing curricular content and classroom activities	Standards; curriculum organization and content; processes (e.g., writing, or design thinking); disciplinary conventions; gradebooks; productivity/workflow systems

literacy (Mills & Comber, 2013), and how educators leverage textual resources to augment instruction (Jewitt, Moss, & Cardini, 2007). What distinguishes this analysis, however, is the conceptualization of these categories as interdependent infrastructures. Whereas scaffolds offer temporary support to help students accomplish tasks, infrastructures are embedded into environments—often in ways that are invisible, and that endure beyond their original intended uses. Scaffolds imply linearity, advancing students, ladder-like, toward understandings and practices. Infrastructures, by contrast, are distributed and agonistic: as they are consolidated with other infrastructures, they produce alignments, frictions, and breakdowns that reshape classrooms' social terrain in uneven and unpredictable ways. A change in textual infrastructure (e.g., using videos to teach content), for example, may obviate established human infrastructures (e.g., in-person direct instruction)—which may compel new infrastructural arrangements that have downstream consequences for what and how students learn. Infrastructural analysis, then, makes legible the ways innovations yield robust and conflictual infrastructural relations that are manifested in (and reshaped through) practice. To explore these relations, I conducted a final layer of analysis, reading the successes and challenges that participants identified in each phase of literacy instruction diffractively (Barad, 2007) through the emergent categories of classroom infrastructure. Doing so allowed me to trace how reconfigurations of infrastructure were associated with students' and teachers' experiences in literacy classroom makerspaces—and to consider how they contributed to or detracted from equitable educational outcomes.

Findings: Innovation and Its Discontents

Findings are organized around two types of friction that surfaced in infrastructural analysis of the literacy classroom makerspaces over time. The first involves the interoperability of infrastructures *across* categories—that is, how different spatial, textual, human, and managerial infrastructures worked with or against one another, including those on which students depended for literacy learning. The second concerns the interoperability of infrastructures *within* a particular category. This refers to the way competing innovations were, at times, consolidated into a single infrastructural category, yielding conflicting expectations for literacy practice.

Interoperability across Infrastructures: Competing Supports for Literacy Learning

When the Innovation School opened, the humanities classrooms were not yet organized as makerspaces. They looked and operated like most project-oriented literacy classrooms in the United States. On a typical day, students sat at tables arranged in a U-shape around the perimeter of the room. The teacher greeted students, introducing the day's activities, explaining how they were related to the overarching unit, and providing content-area instruction relevant to the task at hand. Students then proceeded to work—sometimes independently, sometimes collaboratively—as the teacher circulated to provide support. At the end of class, the teacher reconvened the group, addressing lingering confusions and preparing

students for the next day's activities. It was a familiar structure, and most days it worked reasonably well. But as the year progressed, teachers grew concerned that classes were not living up to their "innovative" potential: in the school's makerspaces, students were experiencing asynchronous learning, but then were reverting to conventional classroom routines for their content-area courses. They worried students would view making as something disconnected from learning in the humanities. These concerns were not unfounded: in year-end interviews, most students associated making strictly with the school's makerspaces—not with content-area classes. The summer before the second year, then, teachers resolved to remake their humanities classrooms into makerspaces.

More than a superficial change, this transformation involved reconfiguring critical infrastructures for literacy teaching and learning (see Table 2). The *spatial infrastructure* of the classroom was overhauled, with the U-shaped group of tables replaced by an open-classroom environment. This space was divided into distinct activity zones that layered elements of makerspaces with residue from earlier literacy-oriented innovations like reading/writing workshops: an independent work area; tables for collaborative projects; spaces for audiovisual devices, art supplies, and robotics kits; a classroom library cart; and seating for mini-lessons (Figure 1). Notably, this arrangement decentralized the space—there was no longer a location from which teachers would provide whole-class instruction. This was because the new organization also reworked the *human infrastructure* of the classroom. If students were to work asynchronously, moving between zones as their making-oriented projects demanded, teachers' roles would also need to change. Rather than facilitating inquiry-driven lessons, teachers now organized their contact with students into three types of meetings: (1) tune-ups (5-minute check-ins about issues in student work); (2) mini-lessons (15-minute small-group lessons); and (3) conferences (10-minute one-on-one meetings about overall progress). In place of formal lesson plans, teachers now mapped their daily schedules to ensure they met with every student in one of these categories each week (Figure 2).

With classroom space and instruction decentralized, teachers needed an alternate way to deliver curricular content to students while still letting them work asynchronously. Doing so involved reconfiguring certain human infrastructures from the previous year into a new *textual infrastructure.* Instead of teachers guiding students through units, instruction was now organized into unit "playlists"—lists of coordinated activities, lessons, videos, and readings, each of which built up to a thematic project. This process of textualization also extended to instruction: because students would work through playlists at their own pace, the contextualizing that teachers did at the beginning and end of classes in the first year was now encoded into blocks of written instructions at the beginning of each activity (Figure 3). Importantly, all of these playlists were also aligned to the *managerial infrastructure,* both of the competency system and of the school's "design process," which became the framework for organizing playlist activities (a focus of the following section).

Table 2. Analytic Chart of Shifts in Classroom Infrastructures (Years 1–2)

Infrastructure	Year 1	Year 2
Spatial	Tables were arranged in a U-shape around the perimeter of the classroom. The teacher sat, stood, or moved throughout this U while interacting with students. The focal point was a whiteboard/projector directed toward the front of the room. A classroom library cart sat along one wall.	Classrooms were organized into distributed zones of activity—independent work, collaboration, mini-lessons, and conferences—with no focal point. Students and the teacher circulated throughout these zones. Storage space was provided for project materials (e.g., audiovisual/art supplies, robotics kits). A classroom library cart sat along one wall. (Figure 1)
Textual	Teacher-facilitated unit activities were supported by a range of worksheets, graphic organizers, videos, and literary texts.	Unit activities were organized into "playlists" that students could work through asynchronously. These included assignments that used many of the same types of texts as in Year 1 (e.g., graphic organizers, literary texts). Additionally, framing information used to explain and contextualize these playlist assignments was now textualized as well. (Figure 3)
Human	Teachers framed unit assignments, facilitated activities and discussions, and provided support for individuals and groups.	The teacher no longer facilitated activities or framed assignments (this was translated into textual infrastructure). Now teachers met with students in three meeting formats: tune-ups, mini-lessons, and conferences. In lieu of weekly lesson plans, teachers created charts to ensure they met with every student in one of these formats. (Figure 2)
Managerial	Inquiry-based units were organized to address competency standards.	Inquiry-based units were organized to address competency standards and structured in the model of the school design process. (Figure 4)

Teachers and students narrated these shifts as enabling autonomy in the classroom, and indeed, the reconfiguration did create openings for agentive practices to emerge. Miguel, a Puerto Rican filmmaker in the school's first cohort, leveraged the new textual infrastructure to complete playlist assignments at home so he could use class time to take advantage of resources in the classroom's spatial infrastructure—specifically, the cameras and video-editing terminals. During a unit on the 2016 election, Miguel used the final project—creating a message to the future president—to write a spoken-word poem about urban underdevelopment. He then turned this into a short film, which was ultimately screened at a local festival.

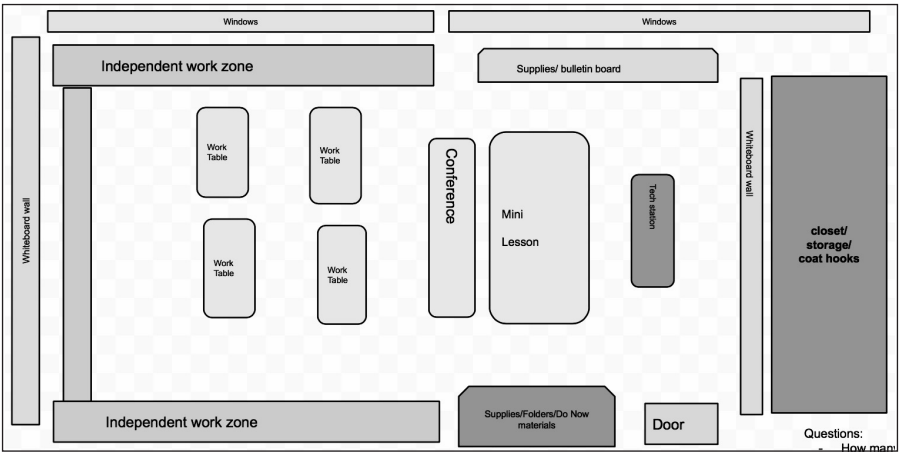

FIGURE 1. *Teacher-generated diagram of the new spatial infrastructure for the classroom makerspaces.*

Class Section:				
Mini-Lessons			Tune-Ups	Conferences
Day	Topic (+ link to lesson)	Students	Student (Topic)	Students
Mon				
Tues				
Wed				
Thurs				
Fri				

FIGURE 2. *This teacher-generated planning template shows the new organization of human infrastructure in the classroom makerspaces. In lieu of lesson plans, teachers filled out this template each week.*

Others, similarly, found that the new infrastructural arrangements opened space for creative work that was not possible in the Year 1 humanities classroom: podcasts, infographics, stories, and videos that explored complex and personal topics, from mass incarceration to mental health (see Stornaiuolo & Nichols, 2018). Educators held up such projects as evidence of the model's success: making, as an innovation, was cultivating richer forms of literacy engagement in their classrooms.

But these examples did not reflect how the majority of students experienced the makerspaces. Field notes from Year 2 show that, on an average day, two to three students might be working on such projects, while the rest alternated between casual coursework, talking with friends, watching YouTube videos, and sleeping. In faculty meetings, teachers attributed these variations to students being "off task," but analysis of student interviews suggests the disparities were tied to the

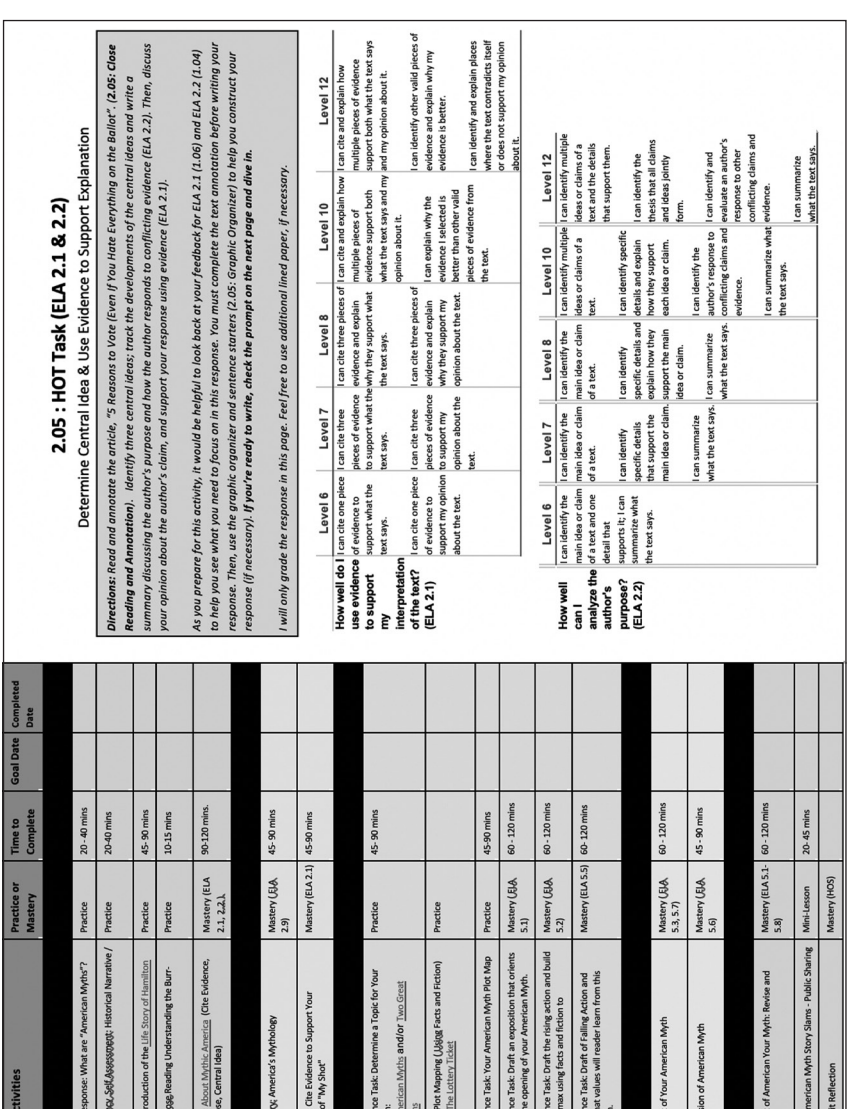

FIGURE 3. Left: *a unit "playlist," the textual infrastructure created to support asynchronous learning;* right: *a playlist assignment, where dense contextual details—once delivered by teachers—became textualized to allow for asynchronous work*

shifting infrastructures of the classroom: the same infrastructures that opened creative possibilities for some students worked against infrastructures on which other students depended to participate. For example, the heightened role of textual infrastructure in Year 2 meant that students now had to navigate dense blocks of technical writing before even beginning to work on an assignment. While students like Miguel found this freeing, others frequently felt disoriented, about not only the

task before them, but also how it was related to other assignments in the unit. For these students, the human infrastructures that had provided context and framing for unit activities in Year 1 were not barriers to autonomy, but resources that helped them find meaning in their work. As these infrastructures were textualized, then, many students grew frustrated with the literacy makerspace, and the "pointlessness" of playlist assignments—a notable disconnect, as the playlist was designed to help students carve personally meaningful pathways through the curriculum.

The interoperability of classroom infrastructures created other frictions. The spatial infrastructure, for example, surfaced throughout student interviews as a persistent challenge. Because, in a given class, students were working on projects, collaborating on assignments, talking with friends, and watching YouTube videos, the literacy makerspaces were lively and chaotic. For those students already straining to navigate the course's dense textual infrastructure, the volume and movements of the classroom exacerbated these difficulties. Many were forced to devise workarounds when the environment became untenable. Selena, a Chicana artist in the school's second cohort, described one such strategy: "Sometimes the class would be so loud, I would just ask to go somewhere else more quiet." Specifically, she retreated to the science room, where she had repurposed a coat closet as a quiet study space. Another student, Kalif, an African American music producer in the school's first cohort, retreated to the school's media makerspace, which had a recording booth that he used for focused reading. But most students did not have such refuges. When the volume became too much, or textual instructions too confusing, many resigned themselves to spending class time talking, sleeping, or watching videos—opting to complete playlist assignments at home. The textual infrastructure allowed for this flexibility, but as many students were juggling assignments with jobs, family responsibilities, and extracurricular activities, in practice, it was difficult to follow through. Thus, many students reported feeling perpetually "behind." As Crystal, an African American entrepreneur in the school's first cohort, put it, "It gets stressful. . . . It's not that the work is difficult. It's just, sometimes you have a hard time catching up."

As literacy classrooms were reshaped into makerspaces, then, the infrastructures intended to support asynchronous learning sometimes undermined other infrastructures on which students depended. These frictions in the interoperability of infrastructure were not felt evenly. Those who were positioned to navigate the dense textual infrastructure with limited teacher-support often found ways to thrive; however, those who were not—or who had family and job responsibilities that limited the out-of-school time they could devote to such tasks—strained to navigate the demands. Such incongruities were not always legible to teachers, who, in the new human infrastructural arrangement, had increased meeting time with individual students, but a diminished sense of a class's collective successes and struggles. From this vantage point, student disengagement was not an upshot of systemic frictions, but a failure of individuals to remain "focused" and "on task." It was those teachers who worked directly with students who sensed that, perhaps, something more structural might be involved. In a year-end interview, Kelly, the

school's learning-support specialist, questioned whether the innovative aspirations of the classroom makerspaces were really serving all students:

> I don't know if I feel like we're innovative anymore. I don't feel successful right now at the things we say we do, which is teaching kids to take responsibility for their own learning and do it in a way that's asynchronous and personalized. I feel like there's so many pieces that we claim to do, and we just miss it.

Perspectives like Kelly's highlight the implications that the interoperability of infrastructures holds for educational equity. The innovative arrangements that open opportunities for those poised to take advantage of them can often undermine critical infrastructures on which others depend. Such incongruities serve as reminders that while the discourse of "innovation" celebrates the disruption of familiar and settled practices, there is no guarantee that new routines that replace them will be more just or equitable if they are not deliberately constructed to support the flourishing of all students.

Interoperability within Infrastructures: Literacy and the Management of Design

A second friction in the literacy makerspaces related to interoperability *within* a category of infrastructure (e.g., spatial, textual, human, managerial), as competing innovations were consolidated to shape its organization. Such frictions are common, in part, because innovations rarely involve clean breaks from past practice, but rather a layering together of the old and new. Indeed, a truly novel innovation would be unrecognizable to us: it is only through historical resonances that a new innovation becomes legible as such (Edgerton, 1999). This is evinced, I suggest above, in the alliance of making and literacy education, as many of the former's approaches to process, structure, and content share close affinities with past innovations in the latter (e.g., process-writing, reading/writing workshops, expanded conceptions of literacy). At times, such alignments lead to generative new combinations. The spatial infrastructure in the Innovation School, for example, seamlessly braided workshop structures (e.g., classroom library, areas for mini-lessons and conferences) with those of makerspaces (e.g., zoned spaces aligned with particular tool-use). The interoperability of these spatial infrastructures reinforced how reading, writing, and making might mutually inform one another—an alignment affirmed by the growing literature on library-based makerspaces (Moorefield-Lang, 2015).

However, interoperability within an infrastructural category was not always so frictionless. At times, the consolidation of competing innovations produced incongruities that undermined literacy instruction and practice. The most pronounced example of this was the layering of the design process with competency-based standards in the classroom's managerial infrastructure. "Design" has a contested disciplinary history (Cross, 2001), but it has emerged, in recent years, as a flexible process for solving problems, organizing practices, and creating products in a range of spheres, from commercial entrepreneurship (Brown, 2008) to feminist activism (Costanza-Chock, 2020). In education, it has become a frame for research methods

(Gutiérrez & Vossoughi, 2010), curriculum writing (Wiggins & McTighe, 2005), and literacy pedagogy (New London Group, 1996). While there are differences in the usage of design across these contexts, it generally involves cycles of planning, prototyping, and refining that lead to deliverable solutions or products—what is often termed *the design process.* Given the proliferation of this process in education and the maker movement (Thomas, 2014), it is not surprising that design became integral to the Innovation School's remaking of literacy classrooms into makerspaces.

Design was central to the Innovation School even before it opened. In an early summer planning session before Year 1, Ben introduced newly hired teachers to the school's design process and led them in a series of "design sprints" to create classroom policies (Figure 4). This design model was printed on posters and hung in every classroom to remind students that design transcended disciplines—it was a universal process that could be incorporated into any subject. In a faculty meeting, Ben articulated this explicitly: "Discover. Define. Design. Develop. Deliver. You can see this in everything. This is a process that's universal." He went on to explain how design provided common language for learning and making across disciplines: "We're framing design in the steps of proposing a lab, making a graphic, analyzing city maps—or writing, or making a photo essay or film."

Between Years 1 and 2, humanities teachers determined that design might help facilitate the transition of their classrooms into makerspaces. As they reconfigured the textual infrastructure of instruction by creating unit playlists for asynchronous learning, they organized them using two forms of managerial infrastructure: competency standards and the design process. Each unit would include activities and projects that allowed students to demonstrate competency in particular literacy practices (e.g., analyzing text structure, evaluating arguments), and these assignments would be organized around the school's design model (see Figure 3). For example, in a unit on American mythology, students were tasked with creating a product (e.g., a video, story, or other artifact) that challenged dominant narratives from US history. For the *discover* and *define* phases of the unit, students would complete competency-aligned assignments: building vocabulary, reading counter-histories, analyzing clips from *Hamilton: The Musical*, and reflecting on their own experiences with The American Dream. These activities were to provide support and resources as students then proceeded to complete the open-ended unit project in the *design, develop,* and *deliver* phases. As Christopher, a white teacher-activist and humanities educator, said, "We put the language of design in our units. We have this exploratory phase at the beginning, and this phase where you're defining and doing research, and this phase where you're creating."

FIGURE 4. *The school's design process.*

This arrangement appeared functional—even generative—on paper, but in practice, there were tensions in the interoperability of these managerial techniques. Where competencies were grounded in specific disciplinary standards related to literacy and the humanities, the school's design process was deliberately discipline-agnostic. In other words, competencies were intended as a managerial infrastructure to organize opportunities for developing literacy practices. While projects were one way to accomplish this, they were a means, not the end, of instruction. The design process, by contrast, was a managerial infrastructure intended to make deliverable products, irrespective of disciplinary methods. As Crystal explained, "[It] is a process. You've got steps . . . but it's got an overall goal at the end. The overall goal is your project being out there." The consolidation of these innovations in the managerial infrastructure of the classroom, then, created contradictions in what it meant to "complete" a unit. From the standpoint of competencies, students completed a unit when they could demonstrate proficiency in its aligned literacy practices. From a standpoint of design, completing a unit meant finishing its final project—which rendered irrelevant any competency-based assignments that were not explicitly related to students' making activities.

Elijah, an African American gamer in the school's second cohort, was one of many students affected by this contradiction. After seeing the project description for the American mythology unit, he was immediately inspired. Having played the game *Assassin's Creed*, which depicted an alternate history where George Washington became king rather than president, Elijah wanted to extend this conceit in a written story. Scanning the playlist of competency-aligned literacy assignments, he determined they were unrelated to the project he had in mind. Instead, he looked online for resources related to Washington, particularly his relationship to slavery. Synthesizing his findings into a fictional narrative, he submitted the final draft titled, "The Darkness of George Washington," and received positive feedback from his teacher, as well as credit for competencies in research and character development. However, he was given an *incomplete* for the unit, as he had not done the competency-aligned *discover* and *define* assignments that were intended to prepare him for the final project. This frustrated Elijah. For him, those assignments were peripheral to the main thrust of the unit—completing the project. He saw little purpose in doing activities that were not consequential for what he was making. "If I did the project, it makes no sense to turn these assignments in too," he said. "I'm not going to write each individual assignment when I could just do the project. It doesn't make any sense to break things down into smaller pieces just to stretch out the unit."

But to teachers, these assignments were not just stretching out the unit—they were foundational to it. And as more and more students skipped them in order to focus on projects, educators grew concerned. In a year-end interview, Christopher expressed this, saying, "We have to get kids finishing things. I think that's been another of the biggest frustrations . . . is students seeing the value in a finished product, and in seeing something through to the end." But students like Elijah believed they *were* valuing the finished product by focusing on the final project, rather than getting bogged down in unrelated procedural assignments.

More than misunderstandings about unit expectations, such incongruities highlight contradictions in the interoperation of the makerspace's managerial infrastructure. As competency-based standards and the design process were consolidated, they each produced a divergent telos: one oriented toward disciplinary practices, and the other toward transdisciplinary projects. These conflicting ends yielded frustrations, but importantly, they also carried implications for equity. While the infrastructure for design conveyed to students the value of their interests and identities in the production process, the infrastructure for competency evaluated students' work against a different set of expectations—assessing expressive, identity-inflected products using a rubric of disciplinary knowledge alone. Likewise, while the infrastructure for competency promised to hone students' disciplinary practices related to reading and writing, the infrastructure for design obviated such work—subsuming these activities into a universal design process and, by extension, withholding resources for meaningful support of disciplinary learning. And crucially, as with the frictions arising in the interoperability of infrastructures, the invisibility of these tensions allowed them to be understood not as systemic contradictions, but as a failure of individual students to navigate the innovative organization of the makerspaces—disadvantaging students for not appropriately responding to the incongruities the system itself produced.

Discussion

Reading across these findings highlights how innovations do not operate in isolation, but through a contingent interplay of infrastructural arrangements whose alignments, frictions, and breakdowns have critical implications for equity. For researchers and educators, then, attending to innovation from below—mapping its infrastructures, their relations of interoperability, and their downstream consequences—makes visible otherwise unseen dynamics as innovations are folded into literacy classrooms. It also highlights how an innovation's infrastructures might alter, threaten, or degrade already-existing infrastructures for literacy learning—advantaging those poised to adapt to such circumstances while making things harder for others. These uneven impacts often reinforce a wider neoliberal logic of "personal responsibility," where individuals are blamed for failing to adapt to systems and structures that undercut their best efforts—either by removing vital supports, or by demanding contradictory practices (Harvey, 2014). When this logic is mapped onto schools and communities that have faced long histories of systemic marginalization and predatory underdevelopment, these uneven outcomes can easily reinscribe raced and classed formations of difference that allow educational injustices to endure.

While this study of innovation from below has focused on particular literacy infrastructures—spatial, textual, human, and managerial—these are not an exhaustive accounting of infrastructures at work in the Innovation School. As I have suggested, infrastructures are embedded—they emerge in relation to other infrastructural arrangements that extend across scales. Though the categories I

emphasize surfaced in analysis as salient features of literacy instruction in classroom makerspaces, other researchers with other questions and methods might attend to other infrastructural relations. The textual infrastructure of the playlist, for example, was tied to a technical infrastructure of the school's one-to-one distribution of Chromebooks—which, in turn, subsisted through both internal relations of platform infrastructure (e.g., hardware, software, interfaces, algorithms) and external relations to wider infrastructures of wireless internet and electrical power. Tracing such relations does not require literacy researchers to be intimately familiar with computer code or electrical circuitry; it requires only that they attend to literacy education's entanglements with other sociomaterial processes. This orientation provides resources for exploring moments of friction when unseen infrastructures announce themselves: as when the internet goes down in a literacy course dependent on Google Classroom. It also makes legible institutional priorities with regard to infrastructural upkeep, as when "innovative" district initiatives find funding for trendy technologies, but not for living wages, books, or reliable heating and cooling (Nichols & Coleman, 2020). Analyzing the interoperability across and within these infrastructural categories, then, attunes educators to the contradictions of innovation, and how the new infrastructural arrangements that result might disadvantage particular students or communities as they are grafted onto school structures with their own embedded legacies of raced, classed, and gendered inequality.

Finally, such contradictions also surface implications for literacy education as it is remade by innovations like making. Because making subsumes a range of practices (e.g., woodworking, programming, crafting), articulating its underlying process is necessarily vague. A design process like that used in the Innovation School shows how such processes may help promote interdisciplinarity, but also elide how design is deeply dependent on disciplinary knowledge (Kafai et al., 2014). An architect, for example, engages in design not through generic stages of development or prototyping, but through the coordination of highly specialized practices: planning aesthetic arrangements; calculating structural loads; analyzing sun paths, wind patterns, and ecological impacts; and accommodating zoning and accessibility regulations. Abstracting such activities into a universal mode of inquiry, like *design,* or a universal category of production, like *maker,* can paper over crucial differences in the technical knowledges required to do architecture—or filmmaking, or analytical writing. It may be possible, in other words, to articulate the writing process as a design process, but doing so may unmoor the former from essential disciplinary commitments, leading to instruction that withholds explicit attention to disciplinary knowledge or practice. Such ambiguities can not only dilute the aims of literacy instruction, but also leave literary making vulnerable to appropriation for contradictory ends: as a resource for student-directed learning, individual entrepreneurship, or job training in resource-rich STEM fields. Studying the interoperability of literacy infrastructures, then, provides a strategy for making visible such contradictions, and, in doing so, for reimagining how alternate infrastructural arrangements might better serve the equitable flourishing of all students.

Conclusion: Toward a Reparative Reform

Studying innovation from below offers a frame for understanding the infrastructures that animate innovations, and their implications for equity. But it also gestures toward alternate orientations for thinking about educational innovation. As Ghiso and colleagues (2013) argue, there is significance in where we imagine the location of innovation—whether we envision it being passed down from university labs or ed-tech entrepreneurs, or emerging from the lived dynamics of classrooms. Since Hubbard Winslow's 1834 address to teachers, *innovation* has meant many things; but its present usage, exemplified in making, tends to locate it outside of schools—an external intervention meant to ameliorate longstanding challenges by "disrupting" existing practice. The Innovation School's origin is an example of this: the students, parents, and teachers whose dissent prompted the school's opening were not protesting for more innovation, but for equitable education in the wake of devastating school closures. It is telling that, for the district, the most readily available answer was not a reinvestment in neighborhood programs—but an "innovative" alternative. This is emblematic of a broader enchantment with innovation—where many would sooner "move fast and break things" or "fail forward" than repair the robust, if fractured, systems that serve the common good.

Such fetishizations of innovation ignore the fact that progress is not linear, that the vast majority of innovations fail. And while "move fast and break things" may be a celebrated strategy in Silicon Valley venture capitalism, it is reckless as a model for developing healthy public programs. In the STS literature, this realization has prompted research that eschews disruption to focus on *maintenance,* the care-work involved in identifying and mending ruptures in the systems on which we depend (Russell & Vinsel, 2018). Such work has focused on roadways and pipelines, but it is equally applicable to education—another commons threatened by privatization, underdevelopment, and austerity politics. This orientation reflects the progressive project to which innovation from below might contribute: a *reparative reform* that attends to infrastructural fissures that arise from practice and threaten human flourishing, and that seeks reparation for the histories of injustice that haunt school systems and literacy classrooms. Such a stance might shift the locus of innovation: to view it not as something external to public schools, but within them; to see the development of an equitable educational commons as one of the most ambitious innovations for which we can strive; and to weigh the value of new trends and technologies by their potential to contribute to or detract from this aim. In other words, this orientation suggests that if *innovation* is to be more than a buzzword, if it is to have value in the project of educational justice, this will not occur through "disruption," but through the patient, material labor of constructing robust and coherent infrastructures for educational equity, from below.

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Appendix A: Data Collection Overview

Data Source	Description
Observations	· Typed fieldnotes/memos (43) · Notebooks of classroom jottings (5) · Recordings from class sessions (~4 hours of fragments) · Recordings from professional development workshops (~16 hours) · Recordings from humanities planning meetings (~4.5 hours)
Interviews	· Interviews with educators (10 total, 60-90 min. each) · Interviews with students (22 total, 20-60 min. each)
Artifacts	· Institutional documents (e.g. school policies, teacher-generated classroom designs/procedures; teacher-generated protocols for discipline, student-support) · Curriculum maps, lessons for humanities classes (3 years) · ~70 student-written assignments, quizzes, in-process and complete (with teacher feedback) · Student-made video projects (6 total)

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