Insights from International Partnerships on Infrastructuring for Maker Education

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Abstract: Maker education is a disruptive innovation spreading globally, fundamentally challenging schooling by shifting focus from abstract ideas to creating and sharing tangible artifacts. Often driven by grassroots enthusiasm rather than top-down mandates, this diffusion lacks corresponding supportive infrastructure from established systems, posing a timely question: *What can be learned about the infrastructures and infrastructuring processes required to support the integration of maker learning?* Maker education offers an opportunity to employ infrastructuring as a conceptual lens and strategy to analyze the inherent tensions between this movement and formal schooling. This structured poster symposia embodies the Annual Meeting's theme, *Partnering with Purpose*. It convenes international research groups who actively collaborate with local stakeholders to share diverse insights from their efforts to integrate maker learning into school systems. By illuminating these infrastructuring processes, we aim to inform a more robust theory of sustainable, systemic change within the Learning Sciences.

Introduction

Maker education, a pedagogical movement propelled by accessible technologies and grounded in long-standing traditions of learning-by-creating, has emerged as a significant force in contemporary education (Schad & Jones, 2020). As a form of constructionism, it positions learning as building sharable artifacts, using technology for learners to express their interests and identities (Resnick, 2017). Though recent, maker learning embodies key learning theories. Its emphasis on tangible creation situates it within sociocultural theories of learning as participation in communities of practice (Lave & Wenger, 1991). This work is also informed by sociopolitical framings that question how educational approaches challenge or reproduce inequities (Vossoughi et al., 2021). Additionally, a post-humanist perspective recognizes the agential role of materials, framing learning as co-creation within human and non-human assemblages (Keune & Peppler, 2019).

The pedagogical vision of maker education creates deep tensions, as its sociocultural and sociopolitical roots conflict with the predominant infrastructure of schooling (Riikonen et al., 2020). Shifting from knowledge acquisition to knowledge creation requires transformation across five dimensions: epistemological, challenging what counts as valid knowledge (Korhonen et al., 2022); social, demanding new roles and relationships that disrupt traditional hierarchies (Vossoughi et al., 2021); material-technological, requiring new tools, spaces, and a view of materials as active partners in learning (Keune & Peppler, 2019); pedagogical, calling for new models of facilitation and assessment (Davies & Seitamaa-Hakkarainen, 2025); and organizational, confronting established structures of time, staffing, and policy (Valente & Blikstein, 2019). These tensions underscore that implementing maker education requires a systemic transformation of schooling infrastructures.

Questions of scaling and sustainability are pressing. Unlike top-down reforms, maker education spreads through decentralized, grassroots movements (Blikstein, 2018). This presents a paradox: schools are adopting this innovation with little development of supportive infrastructure. Without it, maker education's core principles risk assimilation by system inertia, leading to superficial, techno-centric implementations that privilege tools over pedagogy (Valente & Blikstein, 2019). The widespread interest in making is an opportunity for change, but it demands deliberate focus on the necessary infrastructures.

This symposium argues that infrastructuring offers a powerful lens to examine and sustain this innovation. The verb "infrastructuring" focuses on the ongoing work of designing systems as they are introduced into practice (Kashi et al., 2023). We define it as the "activities that aim to redesign components, relations, and routines" shaping maker learning (Penuel, 2019, p. 659). This perspective highlights the emergent nature of design and recognizes the critical adaptations made by local actors to fit innovations to their needs (Chen, 2024).

Our symposium builds upon international dialogue about moving maker education toward systemic, equitable integration (Davies & Seitamaa-Hakkarainen, 2025). This requires addressing questions of justice: who has access, who designs the learning (Gutiérrez & Jurow, 2016), and how can infrastructuring dismantle systemic barriers for marginalized students (Blikstein, 2013)? In alignment with the Annual Meeting theme, *Partnering with Purpose*, we gather to share insights, positioning academic partners as active participants in transforming complex systems, not just observers.

This *Structured Poster Symposium* analyzes infrastructuring work across diverse international contexts. The session will feature a collection of posters introduced by the session chairs, followed by time for attendees to engage with presenters. To synthesize the work, a discussant will offer commentary, leading into a moderated discussion with the presenters and audience. By examining these varied case studies, the symposium reveals effective strategies, identifies persistent challenges, and motivates a new wave of research on supporting educational change. Each presentation contributes to the theory of infrastructuring with practical lessons from maker education, offering valuable insights for the learning sciences and a model for fostering deep, systemic, and sustainable change. The symposium is guided by a central research question: *What can be learned about the infrastructures and infrastructuring processes required to support the integration of maker learning?*

Building beyond spaces: Infrastructuring maker education through cross-sector partnerships in India

Akshay Nagarajan, Alekh Velayudhan, Deepanshu Pathak

Maker education in India expanded through a convergence of federal, state, non-profit and corporate efforts. The Atal Innovation Mission’s (AIM) Atal Tinkering Labs (ATLs), launched in 2016, *India’s first attempt to embed makerspaces in schools nationwide* provided initial funding, standardized equipment, and volunteer mentorship, envisioning a culture of innovation across more than 9,000 schools (NITI Aayog, 2020). This initiative largely positioned makerspaces as infrastructures to be installed, not ecosystems to be cultivated, with limited involvement of state education departments and minimal teacher capacity to integrate maker activities. The Assessment Report of ATLs (Athena Infonomics, 2023) revealed that weak governance, inadequate teacher training, inconsistent mentorship, and funding shortfalls reduced many labs to static installations.

The ATL framework provided visibility and tools, but few mechanisms for operations. Teachers struggled to sustain labs, while schools lacked guidance to transform into meaningful execution. These gaps catalyzed infrastructuring towards building and adapting systems in practice (Penuel, 2019). As educators, NGOs, and EdTech startups collaborated to bridge these gaps, infrastructuring manifested. Startups offered lab-setup services, teacher training, and curricula; universities localized contextual materials. In this ecosystem, infrastructuring became a multi-scalar process that negotiated adaptations across institutions and communities (Karasti, 2014).

The Andhra Pradesh State Skills Development Corporation (APSSDC) offers an infrastructuring model that addresses these challenges systemically. In partnership with our nonprofit–university consortium, APSSDC launched pilot workshops on robotics, computational thinking, and life skills for middle-school students. Building on the pilot’s success, the consortium trained 200 mentors who facilitated makerspaces in over 2,000 public schools. Infrastructuring here unfolded across organizational and pedagogical dimensions. Mentors co-developed curricula, localized facilitation practices, and provided teacher support. Aligning with participatory design perspectives these adaptations blurred boundaries between designers and users (Karasti & Syrjänen, 2004). By embedding mentorship and co-design, APSSDC demonstrated that infrastructuring succeeds when it invests in human capacity rather than focusing only on physical infrastructure.

Corporate CSR partnerships added another layer by linking maker education to sustainability and equity goals. Collaborating with Salesforce, our team developed UNSDG workshops and school-based makeathons, where students prototyped solutions to local challenges (Manikutty et al., 2020). These expanded infrastructuring into sociopolitical and material-technological domains, transforming makerspaces from technical training sites into platforms for community-centered innovation and civic imagination (Vossoughi et al., 2021).

Across these efforts, our role as maker educators and co-designers was to build capacity in resource-constrained schools. Following Papanek's (1971) philosophy of socially responsible design, we developed grassroots curricula using everyday materials and local knowledge to meet community needs. Working at the intersection of nonprofit, academic, and public initiatives, we complemented federal schemes by emphasizing pedagogy, mentoring, and culturally relevant practices that make makerspaces more sustainable and inclusive.

Together, these cases illustrate how infrastructuring in India's maker education landscape unfolds through relationships rather than blueprints. Federal initiatives like ATLs provided scale and visibility. State programs such as APSSDC's added continuity and localization. CSR-academic partnerships contributed pedagogical innovations. Each actor compensated for the others' limitations, forming a layered ecosystem. Persistent challenges remain such as teacher workload, uneven mentor integration, limited curricular alignment, and insufficient evaluation systems. But these frictions affirm that infrastructuring is never complete. Overall, India's maker education movement exemplifies a living infrastructure—an adaptive system co-produced by educators, policymakers, entrepreneurs, and learners. Rather than a top-down transfer of innovation, it is a distributed process of design-in-use that keeps the ecosystem responsive to evolving educational contexts (Chen, 2024).

Infrastructuring maker education through the Brazilian Creative Learning Network

Ann Berger Valente, Leo Burd

The Brazilian Creative Learning Network (BCLN) is a social movement of educators, artists, parents, researchers, entrepreneurs, students, and organizations that encourage transformative education through creative learning. Creative learning (Resnick, 2017) and maker education share a common epistemological foundation in constructionism (Papert & Harel, 1991), to promote the shift from traditional passive instructional methods based on the transmission of standardized content to more active, hands-on, meaningful, and diversified learning opportunities that address children's needs and interests in their cultural context. BCLN began in 2015 as a project of the Lifelong Kindergarten group (LLK) at the MIT Media Lab. As researchers at the Lifelong Kindergarten, the authors were intimately involved in the creation and development of BCLN. Today, BCLN is an independent organization and, while still involved with many of the initiatives, the authors have a more advisory role.

The BCLN is organized in 28 regional hubs distributed across Brazil and administered by approximately 200 BCLN volunteers that mobilize and support a community of over 20K members and nearly 4K schools. In this vibrant community of practice, teachers find needed support and recognition for their work as well as inspiration through both online and in person campaigns, events, meet-ups, and festivals. BCLN also organizes a yearly conference and maintains a dynamic and interactive portal (Valente & Burd, 2024).

Brazil has a strong tradition of progressive thought leaders including the critical, participatory, and dialogic pedagogy of Paulo Freire (1970), whereby the emancipatory praxis of Freire's ideas (Blikstein, 2008) have influenced educational policies, academic research, and pedagogic practice in schools across the country. (Valente & Almeida, 2020). Therefore, instead of introducing a program from MIT to be adopted locally, LLK assumed that there were already many existing initiatives in the country that were aligned with the notions of constructionism and creative learning, however, these initiatives existed in isolation from one another. Adopting a model of grassroots mobilization based upon leveraging the initiatives of like-minded people, while being respectful of the different realities across the country, the strategy was to develop organically into a sustainable and scalable social movement (Andrews, et. el., 2010).

Infrastructuring included a fellowship program to cultivate local leadership. In a country as big and diverse as Brazil, scale can only be achieved through a network of skilled leaders committed to a common cause, but who have the autonomy to mold the work in response to the needs and interests of their local context (Ganz, 2010). There were a total of five editions of the year-long fellowship, reaching a total of 80 educators. Another initiative, the Festivals of Invention and Creativity (FICs), are key opportunities to give voice to educators as their roles transition from curious observers, to users of existing examples, to designers of their own activities. Educators and students learn from one another, are inspired to try new resources, and gain recognition for their innovations during these locally organized autonomous celebrations (Rede Brasileira de Aprendizagem Criativa, 2024). Over 100 FICs have been organized since 2017 reaching nearly 150K participants.

To welcome people at different positions in their journey, the program must offer multiple entry points and the flexibility to benefit from each individual's professional experience including the social, economic, and cultural particularities of different Brazilian contexts. It also involves an ecosystem of committed stakeholders including policymakers, community leaders, researchers, and families. Sometimes this involves embracing less than perfectly aligned activities that don't yet take full advantage of digital technologies. However, in the spirit of a learning community, we try to make space for everyone's contributions, while spotlighting those experiences that are most aligned with creative learning, and providing tools and opportunities to encourage self-reflection and refinement of the shared practices. BCLN has demonstrated some promising approaches in this direction, but further research is needed to analyze the detailed impact of such initiatives.

Malleability of clay extrusion as driver of the AMC Edu:Lab Infrastructure

Anna Keune, Živa Simšič

As sustainability gains prominence in education (UNESCO, 2020), urgency for novel technologies that can transform high-carbon industries in education grows. One such industry is construction, a major contributor to global greenhouse gas emissions (UN Environment Programme, 2024). Yet, construction is undergoing change through sustainable materials and innovative technologies, including robotic 3D printing with clay (Agnusdei & Del Prete, 2022). However, limited research exists on how technologies developed for architectural and construction research drive infrastructural design toward their effective introduction into learning environments for young people. The design of the AMC Edu:Lab to provide early learning experiences with digital technologies and 3D printing offers a case study for understanding whether and how materials like clay and robotic extrusion shape infrastructural design.

Design approach. We adopt a stance of careful coboting (Treusch, 2020), emphasizing the emergent, relational qualities that arise through human-robot interaction, and expand this stance to include clay as active co-creator of infrastructure. Clay is a driver of sustainability in construction, demands particular set-ups, and presents an age-appropriate construction material. Clay shaped the design and implementation of the AMC Edu:Lab infrastructure: (1) *mobile infrastructure*, (2) *learning activities*, and (3) *knowledge infrastructure*, each developed through co-design with clay's viscosity, drying behavior, and messiness. We documented the design process through multi-model data, including designs, order lists, learning activities, and logistical notes. Retrospective analysis included identifying unexpected turns in the design process that we could trace back to learnings about the clay's requirements based on how clay pushed back against human intentions.

AMC Edu:Lab mobile infrastructure. The mobile infrastructure includes two carts for clay extrusion. One cart houses a UR10e robotic arm and essential components (e.g., air compressor, extruder). The other cart contains high- and low-tech craft materials (e.g., 3D pens, clay modeling tools). The need to respond to clay's material demands exposed logistical and technical frictions that turned into productive sites of co-design that led to new and unexpected design iterations (e.g, creation of shelving for drying clay projects).

AMC Edu:Lab courses. Clay became a co-actant in scaling down construction processes for education. Clay extrusion featured in programs for youth aged 10–18, from short workshops to semester-long courses. Working with clay redefined sustainability in construction, emphasizing material optimization, robotic path planning, and design for disassembly. Clay's drying time and fragility revealed construction's temporal and material limits, prompting a cooking show format with stages prepared in advance. This allowed participants to experience the full printing cycle while foregrounding processes often automated in PLA-based printing. Through clay's demands, sustainability became tangible, practiced through timing, material care, and adaptive design.

AMC knowledge infrastructure. The AMC Edu:Lab is embedded in a consortium of architects and civil engineers, and laboratories where large-scale extrusion happens. While we aimed to develop a self-standing mobile-infrastructure, clay still requires strong ties to the research landscape of the consortium (e.g., cleaning clay cartridges in specialized laboratories). The infrastructure needed for clay extrusion in education was emergent. We connected with experts when clay's behavior or technological limitations required intervention, revealing knowledge infrastructure as an active site of collaborative exchange rather than a static support system.

Studying how materials generate infrastructural demands is essential for introducing novel technologies that promise to advance sustainability into education. In the AMC Edu:Lab, observing how clay pushed back on human intentions and expectations showed how material, technological, and human actors co-produced the infrastructure required for fostering novel learning about sustainability in construction.

Multi-level Infrastructures for integrating maker learning into schools in Finland

Pirita Seitamaa-Hakkarainen, Tiina Korhonen, Laura Salo, Kai Hakkarainen

The purpose of this contribution is to examine the role of multi-level infrastructures in integrating educational maker culture into schools. Our research views learning as a collaborative pursuit of innovation through the design and invention of complex artifacts (Riikonen et al., 2020). In line with the RPP model, we collaborate with teacher teams, positioning ourselves as researchers, learning designers, and co-creators of maker projects. Students are encouraged to engage in iterative and nonlinear efforts to find innovative solutions to complex problems. Building on our experience, we explore the infrastructures needed to expand maker learning in Finnish primary and secondary schools. We identify infrastructures at three levels: macro (national), meso (organizational), and micro (pedagogical practices). Additionally, a crucial cross-level grassroots Innokas Network supports teachers in building collegial agencies, which is essential for bridging these infrastructures (Korhonen et al., 2022).

Macro-level infrastructure refers to nationwide and institutional structures that support educational renewal and maker activities. Finland has a tradition of mandatory craft education from grades 1 to 7, with two to three hours of instruction weekly, and specialized classrooms equipped with textile and technical tools, including digital milling machines, 3D printers, and laser cutters. Teachers are highly qualified, holding master's degrees in technical and textile crafts. The curriculum involves students in the entire creative process and highlights subject integration, creating opportunities for interdisciplinary projects and collaborative co-teaching.

At the meso-level, organizational infrastructures are provided by municipal education providers and schools to guide pedagogical and technological integration. Municipalities allocate funds to public education, and schools have the autonomy to customize the national curriculum. To support maker activities, many schools are renovating spaces, replacing traditional furniture with open, adaptable layouts (Reinius et al., 2021). Furthermore, school cultures must promote teachers' teamwork for projects, which requires collaboration with researchers. A multi-level RPP with Helsinki (2018-2024) enabled us to provide substitute teachers and opportunities for researcher-led workshops, feedback, and co-design of co-invention projects.

Micro-level pedagogical infrastructures are essential for creating tailored conditions that enable co-invention projects. Riikonen et al. (2020) identified four types: epistemic, social, material-technological, and scaffolding. The epistemic infrastructure involves providing open-ended co-invention challenges and modeling maker processes, where goals, methods, and products are unpredictable. It guides processes through evolving visualizations, prototypes, and artifacts, aligning with learning goals such as participatory design. Social infrastructure involves organizing students' teamwork and assigning them expanded creative roles, such as process organization or examining user needs (Bosch et al., 2022). Material-technological infrastructure includes tools and spaces for creating artifacts, both traditional and digital. Finally, scaffolding infrastructure involves guidance practices, such as cross-age tutoring, to help students master complex technologies and tasks. Models like the Double Diamond design model can be used to illustrate the creative process and help students understand its iterative nature. Managing uncertainty during the creative process is vital but challenging, requiring teachers to adapt to emerging ideas. To support teachers, researchers have co-taught and reflected on projects with them

While infrastructure at the national, regional, and school levels supports maker learning, developing teachers' collegial transformative agency is crucial. The Innokas Network, established by Korhonen (2022), plays a vital role in promoting maker education through a RPP. Over the course of two decades, it has evolved into a sustainable grassroots network comprising 750 schools, area coordinators, trainers, and workshops that engage hundreds of teachers and students annually. Its goal is to create innovative schools that integrate digital technology, collaboration, leadership, and team-based learning. The network provides participatory training, consulting, and events across Finland, organizing annual national programming and robotics tournaments. This collaboration and joint activity supports the overall cross-level infrastructure, connecting development, research, and dissemination. The Innokas Network serves as an adaptive research-practice platform connecting grassroots actors with researchers to promote ongoing innovation. This two-way system enables on-site research on education in a digital society and shares research findings by involving practitioners from the beginning.

In conclusion, this contribution examines multi-level infrastructures essential for integrating maker learning into education. We view maker learning as an infrastructured ecology that encourages creative participation and collaborative invention. While the institutional and organizational infrastructures remain relatively stable, it is the partnership and actions of teachers and researchers that are vital in transforming the affordances of these infrastructures into educational innovations. Although different infrastructures can be identified for analytical purposes, they are sociomaterially intertwined.

The Case of an Indian pop-up makerspace

Alekh Velayudhan, Chandan Dasgupta

Places like hackerspaces, schools, museums, libraries and online communities are key to the growing Maker movement. In this project with sixth-grade students, we organized a four-day engineering design making activity at a public school in Mumbai, India. To that end, we operationalized the idea of pop-up makerspaces (Halverson & Sheridan, 2014) to reconfigure existing infrastructures into temporary but functional making environments. As we think with posthuman perspectives (Keune, & Peppler, 2019), intriguing ‘‘hot spots” glowed in this project regarding infrastructuring, involving various human and nonhuman actors at multi-scalar levels.

The school was located close to the research team’s workplace, enabling partnership with teachers and students in exploring how students solve open-ended problems through making. The four-day activity, aligned with the school timetable, included three one-hour and final three-hour sessions. The research team formed groups of three to four students randomly. Drawing on their recent lessons on the laws of motion, students were given the design challenge to make a toy vehicle that travelled in a straight line for a considerable distance using everyday materials - straws, tapes, foam boards, elastic bands, bottle caps etc. Framed as a friendly competition, the activity encouraged movements and collaborations in the classroom which were novel forms of participation in a knowledge-acquisition culture. This pedagogical infrastructuring aimed to bridge students’ familiarity with school competitions and new, inquiry oriented forms of learning. The research team ran the science class in the teacher's absence. Students were positioned as knowledge creators and mistakes were normalized, where we acted as maker-educators, designing and orchestrating the activities. Such social infrastructuring disrupted traditional power hierarchies (Vossoughi et al., 2021). The absence of regular teacher posed challenges since the researchers were outsiders, but we had to ensure students were available for next classes. This organizational infrastructuring involving *time* (Valente & Blikstein, 2019) was at odds with the social dimension, since we had to re-establish power hierarchies to enforce time limits for the activity.

Material and spatial infrastructures also shaped the reconfiguration. The default layout as in typical Indian classrooms, desks and benches faced the teacher, but this orientation hindered collaborations. This forced students to sit face-to-face on either sides of desks for collaborative engagement. The (re)arrangement opened dialogic epistemic relations and fostered “collaboration through air” (Kafai & Harel, 1991) as teams had visibility to other teams’ making. Example: Student A: “*Will the shape and size also matter?..Theirs is so plain [referring to other team’s prototype]”*. The entanglements among the pop-up makerspace and the class schedules glowed as student *B* worried: “*Do we have to finish today only?”*. At the micro-levels, everyday materials continued to be part of the infrastructuring as they resisted, accommodated, and surfaced STEM concepts. The exchanges involving students (C, D) and the materials illustrate such an example where C directed D: “*Hey, just paste the wheels”*, and D responded*: “No! The problem is not with wheels… air coming out of here is not enough for it to go”*.

This case showed that infrastructuring need not always require building new spaces but can mean reconfiguring existing institutional systems - spatial arrangements, class schedules, norms of instructor-student interaction - to make possibilities for making. In this case, the classroom desks *became* workbenches and everyday materials *became* STEM tools. It showed the situational and opportunistic ways of infrastructuring at the organizational levels, and makers with materials *together* drove the learning paths at the micro-levels. By blending the institutional materialities of the school with the material agencies of making, the pop-up makerspace *became* a living example of infrastructuring, enacted in practice through people, matter, and time.

Art-making for social emotional learning: A professional learning community of educators, researchers, and artists

Erica Halverson, Roey Kafri

The UW–Madison Community Arts Collaboratory creates and supports research-based opportunities for youth and educators to grow as learners, to cultivate well-being, and to advocate for social change in and through art-making. Specifically, we leverage art-making practices and routines to support social-emotional learning (SEL) and identity work (Lashley & Halverson, 2021). We refer to these practices as “art-making” in recognition that arts education and maker education have historically been siloed areas of research and practice but that they share theoretical roots and pedagogical goals (Halverson & Sheridan, 2014). This Arts Collab project focused on designing, facilitating, and analyzing a professional learning community (PLC) for school-based educators. Our team of eight university partners and eight educators designed and implemented the PLC, bringing together eight school-based educators to support them in integrating SEL and art-making strategies and activities into their teaching. Our early analyses indicate that teachers’ experiences with arts-based, embodied professional learning and reflection helped them develop teaching practices focused on joy, care, and social-emotional well-being. We set out to design a safer, supportive, and collaborative space for school-based educators to reflect on their own practice; experience UW Arts Collab art-making and SEL routines, practices, and core values; and reconsider, refine, and/or rebuild their own practices and routines based on those embodied learning experiences. Infrastructural takeaways that we have found from our PLC work including the following:

The fallacy of time. One of the most prevalent themes across arts artifacts dealt with the impact of arts and SEL routines and practices on conceptions of time. Members of the PLC often remarked on how art-making activities felt "out of time" or allowed us to "slow time down" or simply to "take the time" to do something. PI Yorel Lashley called this the "fallacy of time" an idea originating from indigenous cultures challenging linear and Western conceptions of rigidity around time (Pranis, 2005). The fallacy of time connects directly to *organizational infrastructuring* which requires confronting the established structures of schooling that are seemingly immovable in our quest to make substantive changes in the teaching and learning ecology. Our work encouraged educators to challenge the constraints and limitations of time through arts and SEL practice.

Balancing structure and "fun" in the PLC. PLCs are most effective when they balance structure with creativity, as this combination supports professional growth and mirrors effective teaching practices (Paniagua & Istance, 2018). In our PLC workshops, sessions intentionally combined structured discussions with hands-on activities. In this work, we were engaging in *pedagogical infrastructuring*, both as a community and as a model for how educators might bring this work forward into their classrooms. Specifically, art-making activities helped create a supportive space for risk-taking and collaboration.

Embodied learning, SEL, and becoming students. Embodied learning disrupts assumptions that students are empty vessels to passively receive knowledge by promoting a more holistic and agentic approach to engagement and the importance of sociophysical contexts in the learning process. *Social infrastructuring* happened through modeling, where PLC participants take on the role of students to understand how power dynamics between students, educators, artists, and even materials might be disrupted, changed, questioned, and built anew.

Creating a safer space for learning. Participants' most important takeaways from the art-making space were tangible ideas for how to focus on the learning environment as a safe(r) space for young people, enabling vulnerability and creativity, building relationships & trust among participants, and valuing ourselves and others as non-experts. These characteristics look like *epistemological infrastructuring* where we fundamentally reconsider who, where, and how we know.

Infrastructuring from within: Co-designing AI literacies in a project-based high school in Southern California

Santiago Ojeda-Ramirez, Kylie Peppler

While makerspaces have proliferated across California's public libraries, inequities in funding, staffing, and access continue to shape who participates (California State Library, 2024). Many programs still serve patrons who already have the time, resources, and digital familiarity to engage. These uneven patterns echo critiques that the maker movement, despite its democratizing promise, often reproduces exclusions found in traditional STEM spaces—privileging white, male, and middle-class participants while limiting the participation of young women and Latinx youth (Calabrese Barton et al., 2018; Nation & Durán, 2019). Yet critical making offers an alternative that draws on learners' sociocultural knowledge and community practices to broaden definitions of science and technology. In this spirit, our partnership approached a public high school in Southern California—where project-based learning through making and STEAM is institutionalized for Latinx youth—as a site to explore how critical making can take root within formal schooling.

Our collaboration with this school (83.5% Latinx students) examined infrastructuring as ongoing negotiation. Through a co-design partnership among university researchers, teachers, and students developing AI-literacy curricula, we foregrounded intergenerational dialogue and examined how power imbalances between adults and youth shaped participation (DiGiacomo & Gutiérrez, 2016). This process expanded teachers' practices toward civic-minded design and positioned students as co-designers whose lived experiences informed the creative process (Mawasi et al., 2023). Yet even within this maker-oriented context, infrastructuring revealed persistent struggles over what counts as knowledge, how authority circulates, and how tools sustain equitable participation. Rather than inventing new technologies, we provoked reflection on the school's existing infrastructures—inviting participants to reimagine how AI tools such as chatbots or model-training interfaces might extend or challenge their practices of making.

Across interviews, field observations, and co-design recordings, three patterns emerged. First, epistemic renegotiation: critical making centered Latinx youths' community knowledge as the basis for design, broadening what counted as legitimate expertise (Nation & Durán, 2019). Second, social reconfiguration: although the school favored project-based learning, teachers still occupied expert roles; redistribution of authority remained uneven. Co-design positioned students as advisors contributing cultural and algorithmic expertise (Noh et al., 2025), yet such shifts required continual work. Third, material-technological negotiation: even with well-equipped fabrication labs, integrating AI tools into tangible creation posed challenges. Teachers and students experimented with connecting digital fabrication typical of AI systems to physical making. As Keune et al. (2024) show, AI can augment learners' drawings while obscuring process transparency; likewise, Keune and Hurtado in Humburg et al. (2025) note that moving between digital and tangible modalities fosters understanding of AI's opacity. In our sessions, AI functioned as a companion *and* co-ideator—a generative partner shaping both concept and artifact. Students adapted AI models to imagine more just, community-oriented technologies, positioning AI as both medium and matter of design.

These findings suggest that infrastructuring in education extends beyond material access to the relational, epistemological, and ethical reconfiguration of making itself. In this Latinx-serving high school, we observed what Calabrese Barton and Tan (2020) term *rightful presence*: moments when students' cultural and civic experiences gained legitimacy within institutional discourse. Through designing AI-powered applications addressing community issues such as labor inequities or food insecurity, students claimed space, voice, and belonging within public education. Ultimately, infrastructuring persisted at the meso level—through subtle negotiations among knowledge, relationships, and pedagogies that sustain equitable participation. As Penuel (2019) argues, infrastructuring evolves through practice. Our work shows it remains active rather than completed—sustained through reflection, adaptation, and partnerships that expand the ethical and pedagogical possibilities of making. Future collaborations among schools, researchers, and libraries can expand equitable access to making and AI literacy, fostering the relationships that sustain justice-oriented learning.

Toward re-mediating unjust infrastructures: Tracing researchers' and educators' infrastructuring practices within an RPP

Ronni Hayden, Ricarose Roque

The Facilitating Computational Tinkering (FCT) project is a RPP between educators and researchers that include the Tinkering Studio at the Exploratorium, Denver Public Library, the Lifelong Kindergarten research group at MIT, and the Creative Communities research group at University of Colorado Boulder, along with an international network of community-based organizations. Our shared work recognizes the important work of informal learning educators in supporting equitable learning experiences for youth and families — as well as the importance of providing educators with needed professional development, resources, and time to deepen their equity-oriented work (Vossoughi et. al, 2016). In this RPP, we seek to actively engage learners in computational thinking through *computational tinkering*. Our approach to computational tinkering aims to broaden the styles of engaging with computing, providing a more social, physical, and cross-disciplinary alternative to more dominant ways of teaching computing that focus on planning and optimization of a single solution (Resnick, 2017).

Researchers played a variety of roles including co-designing computational tinkering tools and activities with educator partners. We called our collaborative process "R&D threads" to capture our iterative, collaborative, and nonlinear design process which interweaved materials and ideas that converged and diverged into new threads. The process was just as valuable as the products as both educator partners and researchers developed new insights from their material explorations (Moreno & Roque, 2023), explored computational tinkering possibilities, and strengthened their collaborative relationships.

As educator partners applied these R&D threads into their specific settings, our research team documented the ways that educators' re-mediated their material, social, and knowledge infrastructures within and beyond their institutions to support equitable participation. We developed a theory of *lines of infrastructuring* to surface and trace educators' practices over time as educators navigated their infrastructures (Hayden & Roque, 2024). Applying this framework to educators' iterative design practices allows us to make visible the patterns of decision making in this work and categorize how infrastructural factors and educators' own values are impacting the implementation of novel activities in their spaces. For example, motivated to invite emerging immigrant groups in their community, educators might create new signage in various languages to decenter English and revise an activity prompt to make it culturally meaningful.

In this poster, we will highlight the intertwined R&D threads and the lines of infrastructuring across the RPP as university researchers, technology designers, and educator partners strived to "make coding meaningful" in making and tinkering spaces. This collective work impacted the early development of the OctoStudio coding app and computational tinkering activities that used the app in different learning environments. In addition to the development of these project outcomes, tracing the infrastructuring work surfaced the ways that RPP partners redesigned, repaired, or re-mediated the roles, processes, knowledge production, and technology design within the

RPP. For example, educators typically had to adapt their infrastructures to accommodate the designs of computational technologies. In this RPP, the technology designers were adapting the technical infrastructures of the mobile app in response to the infrastructuring work of educators' as they tested prototypes of OctoStudio and shared their experiences working with youth and families.

In examining the collective work of educators and researchers in an RPP context, we surfaced key infrastructures and the embedded values in those infrastructures — and how their infrastructuring work questioned and challenged these values to repair, redesign, and sometimes create new infrastructures that instead imbued these infrastructures with the needs, values, and knowledge of their communities. Such work can potentially create more resilient and more just infrastructures.

The IDEIA project in the city of Sobral: Infrastructuring in the Global South

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The IDEIA (*Invenção, DEscoberta, Investigação, Aprendizagem*) project is a long-term RPP focused on transforming science education within Sobral's public schools, a mid-sized city in Brazil's Northeast (Hochgreb-Haegele et al., 2022). Prior to the project, science teaching was quite traditional, relying on lectures and textbook reading. In 2017, a partnership between the Secretariat of Education and our lab started to reimagine STEM learning in the city. We proposed an "integrative approach" that involved redesigning the science education system by aligning curriculum, pedagogy, and infrastructure to create sustainable systemic change. This approach centered on five key components: (1) developing new science standards, (2) implementing a comprehensive teacher professional learning program, (3) designing and launching new laboratories and makerspaces, (4) establishing a new type of teachers in the public network, called the Pedagogical Redesign Teacher (PRT), who connect curriculum, laboratory practice, and classroom enactment, and (5) creating lesson plans aligned with the new standards. Building and linking these pillars involved an "infrastructuring" analysis to intentionally create a complete and self-sustaining educational ecosystem that promotes systemic change and long-term sustainability, emphasizing coherence from classroom practice to municipal legislation.

Importantly, this infrastructuring process was designed and developed over time through direct collaboration with various stakeholders, including middle school science and elementary teachers, teacher educators, policymakers, and researchers. Participants engaged in periodic meetings, workshops, and iterative cycles of curriculum design and classroom experimentation. Researchers positioned themselves as co-design partners rather than outsiders, bringing in evidence-based frameworks, international benchmarks, design-based research methods, and research findings involving teachers and students. Teachers' expertise and classroom experience were central to the project, shaping its development and confirming each step. Through multiple collaborative cycles of planning, implementation, and reflection, the project's elements were continually assessed, refined, and adapted (Penuel, 2019). This infrastructuring process can be examined through three dimensions:

Material-Technological: The IDEIA labs form the core material and technological infrastructure of the reform. These modular spaces were intentionally planned to accommodate entire classes and designed to prioritize group work, combining tools and materials to enable teachers to develop custom toolkits tailored to their learning goals. Moreover, toolkits for classroom use were jointly developed by researchers and teachers. These toolkits were created to align with the new standards and the curricular units developed.

Social-organizational: The introduction of the full-time PRT role represented a fundamental organizational shift in school staffing and educational policy. The position provides dedicated, expert support for integrating the makerspace and science practices—tasks that regular classroom teachers, limited by time and workload, could not effectively manage alone. Another component of the social-organizational infrastructure involved the co-design process, which included researchers and local teachers (Fernandez et al., 2023), as well as co-design sessions between PRPs and classroom teachers (Brasileiro et al., 2021).

Pedagogical-epistemological: The project signified an epistemological shift in how scientific knowledge and learning are defined in classrooms. Instead of emphasizing memorized facts, the IDEIA standards are based on the engagement in scientific practices (Osborne, 2014), expecting students to act as epistemic agents actively involved in building collective knowledge (Ko & Krist, 2019). We began by designing standards aligned with this vision, but over time, we realized that this approach was insufficient. Therefore, new curricular units were created to help teachers implement this vision. These units were validated and refined through professional development sessions where teachers experienced the activities as learners to reflect on their usefulness, challenges, and potential classroom applications.

We were fortunate to lead this project for 8 years with a relatively stable group of teachers and administrators. That showed us that implementing complex educational reforms in a Global South country is feasible but demands creativity and flexibility in building infrastructures—even when we need to deviate from mainstream literature (including our own previous work!). We recognize that having this extended period is atypical, and we are working on designing models to expedite the process without compromising quality.

Discussion

Collectively, these nine papers offer a rich response to our guiding question: What can be learned about the infrastructures and infrastructuring processes required to support the integration of maker learning? By examining diverse international partnerships, this symposium transcends simplistic models of implementation. Instead, it illuminates infrastructuring as a deeply contextual, relational, and emergent process. While many cross-cutting themes emerge, we highlight three specific "rise-aboves" here that will, among others, frame our discussion: the diverse models for infrastructuring, a collective push on the core infrastructural dimensions, and the critical role of equity and justice in this work.

This cross-case analysis reveals that infrastructuring is a spectrum of strategic action, not a monolithic process, with four distinct models. The first, systemic integration, aims for large-scale, coherent change. Examples include the work of Seitamaa-Hakkarainen and colleagues leveraging national policies in Finland and Fernandez et al. co-designing an entire city's science education ecosystem in Brazil. A second model, grassroots mobilization, builds change from the ground up. This is seen in the work of Valente and Burd connecting change agents into a national movement. Third, responsive partnership involves research and practice co-evolving to fill gaps in existing contexts. This includes the work of Nagarajan, Velayudhan, and Pathak supporting federal initiatives in India, Hayden and Roque tracing how educators adapt practices, and Ojeda-Ramirez and Peppler co-designing from within a school. Finally, emergent reconfiguration focuses on how infrastructure is reshaped by immediate conditions, illustrated by Velayudhan and Dasgupta's pop-up makerspace and Keune and Simšič's material-led work where clay co-designed the learning environment.

Beyond identifying diverse models, these papers collectively deepen and complicate our understanding of infrastructure's core dimensions. Perhaps most provocatively, Keune and Simšič's work with clay extrusion advances a "more-than-human" perspective, demonstrating how the material itself—with its specific properties and demands—becomes an active agent in co-designing the mobile, pedagogical, and knowledge infrastructures. This decentering of the human designer resonates with Velayudhan and Dasgupta's analysis of how classroom furniture and everyday materials shaped student collaboration. Furthermore, Halverson and her colleagues challenge the immutability of organizational infrastructure with the concept of the "fallacy of time," suggesting that art-making practices can create temporal spaces that defy rigid school schedules. The work of Fernandez, et al. in Brazil, meanwhile, pushes the epistemological dimension by transforming a city's science standards away from memorized facts and toward engagement in scientific practices, recasting students as epistemic agents who build collective knowledge.

Finally, this symposium underscores that infrastructuring is a sociopolitical act, a site where issues of justice and equity are constantly negotiated. This work is not a frictionless process of implementation, but one fraught with tensions. These tensions surface in the Indian pop-up case, where pedagogical goals conflicted with rigid organizational timetables, and in the Southern California high school, where traditional teacher-student power dynamics persisted despite a project-based ethos. Yet, these sites of friction can also become powerful levers for change. For instance, Ojeda-Ramirez and Peppler show how co-designing with Latinx youth to create AI tools that address local community issues—such as unfair labor conditions—transforms making into an act of "rightful presence" and civic agency. This reframes the epistemological work of infrastructuring as an explicitly political one. Similarly, as Hayden and Roque argue, these challenges become productive opportunities for re-mediating unjust systems. By tracing educators' "lines of infrastructuring," we can see how practitioners actively repair and redesign systems to be more equitable and responsive to their communities.

In summary, these three cross-cutting themes—the diverse models of action, the push to redefine core infrastructural dimensions, and the framing of infrastructuring as a sociopolitical act—provide a powerful framework for understanding the work presented. This symposium will offer a unique opportunity to discuss these themes, among others, drawing on the rich, international cases to gain new, collective insights. Our goal is to move toward a more robust and critical understanding of the infrastructural processes involved in fostering deep, sustainable, and equitable maker education worldwide.

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