



The Future of Maker Education

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Abstract: The influence and reach of maker education continues to grow, bringing new possibilities for hands-on, student-centered, design-oriented, and/or transformational learning to more people in more spaces. Maker education has also more recently attended to issues of justice, equity, and culture. What does the future of maker education hold? What materials and practices will these spaces offer next? What support do teachers need to enact pedagogically sound and culturally relevant learning? How will developing technologies respond to teachers' and learners' needs for accessibility and sustainability? How will maker-based learning be documented and assessed? To answer these and other questions, we propose convening a panel on the Future of Maker Education to both solicit panelists' ideas on the future of maker education and foster audience discussion around these issues.

Symposium overview

Despite being inspired by several other previous educational ideas and reforms, Maker education as a mainstream movement gained prominence only about ten years ago. However, this rapid rise and expansion into schools has raised crucial questions around its educative purposes (making towards what ends?), cultural processes (the 'how' and 'for whom' of making), and conditions that support expansive making (the design and practice of maker education, and educator learning) (Vossoughi et al., 2016; Barajas-López & Bang, 2018). These questions will continue to drive research on making and learning, and their answers are transforming our understanding of both making, learning, and the relationship between the two. How might educational making transform schooling, and how might research on educational making transform the learning sciences? We propose this panel to convene researchers and thinkers towards answering these questions for future of maker education.

We anticipate that the next decade of work on maker education will pursue multiple paths to disrupt the dominance of traditional STEM schooling goals, outcomes, and identities in order to better serve more learners. One such approach is the study and inclusion of cultural making practices that “powerfully engage youth with the political, human, and social challenges of subverting and transforming one’s reality through powerful tools and representations” (Blikstein, 2020, p. 125). In particular, recognition of arts practices as assets that young people bring to learning can offer one way to turn to desire-based scholarship and pedagogy and create equitable education systems. Other researchers advocate for pedagogical designs and practices that nurture justice-oriented forms of worldmaking with students, educators, and communities (Simpson, 2009) and highlight the relationships between making and forms of political education that intentionally weave together critical social analysis, the imagination of possible futures, and the creation of lived-in elsewheres in the here-and-now (Vossoughi, 2014). Yet another approach focuses on recasting the relationships among materials and people to increase inclusion and equity in historically inequitable domains (e.g., Keune et al., 2019). For example, materialized action proposes a new way of integrating (rather than excluding) worldly concreteness into the mathematics classroom, promising a new kind of relatability that may shift participation structures.



In this session, we will discuss how these and other approaches will shape both the research and practice of maker education going forward. We have invited researchers whose work has been foundational in the field to share their thoughts on the future of maker education. We organize the symposium in *four sections*:

1. The chair introduces the topic and gives each presenter 5 minutes to share their thoughts (30 min)
2. Panelists will respond to each others' presentations and to questions from the chair (20 min), including:
 - a. How do you see maker education efforts addressing the criticisms of cultural-insensitivity, hegemony, or exclusivity?
 - b. From both an environmental and curriculum standpoint, how do you anticipate maker education rising to meet the challenges of sustainability?
 - c. As currently new maker technologies become more accessible and novel constructive possibilities arise, which tools or practices most excite you for their potential?
3. Our discussant synthesizes and reflects on the shared ideas (10 min)
4. We will close with a Q&A session for the audience and panelists (15 min).

Innovative features

ISLS introduced for the first time the possibility of “innovative” symposia formats. We intend to take advantage of this possibility by generating more in depth materials that could be accessed before and after the event. Our symposium will have two innovative, “long tail,” hybrid features:

(1) Video interviews between the symposium authors: If the proposal is accepted, from March to May we will organize about 6 “interview sessions” in which the authors will interview each other via Zoom for about 10 minutes. Authors will have a chance to articulate their critique and their imagination of possible futures for maker education with more time and in collaboration with a colleague.

(2) Testimonies of teachers and students on their experiences and ideas for maker education: Respecting research ethics and parental consent, we will select participants in each of our research sites and projects, and ask teachers and students volunteers to record about 10 short video/audio testimonies on meaningful, problematic, or promising practices within their classrooms or communities.

All the videos will be posted on the symposium webpage and on YouTube. Around April 2023, we will ask the ISLS organizing committee to include the link to our website in their regular conference communication, so that attendees can watch them before the conference, comment, and ask questions. These will help inform the final presentations and discussion at the conference. After the symposium, ISLS members would continue to have access to the pre-conference materials and the actual video of the symposium.

The following six briefs summarize the participating panelists' work and potential contributions toward the discussion on the future of maker education.

Arts practices as assets as the future of maker education

Erica Halverson, UW Madison

The rise of the STEM movement has provided a fruitful context to re-insert the arts into conversations about what counts as education through the introduction of STEAM, especially if we aim for a “mutually instrumental” relationship between the arts and STEM (Mejias et al., 2021). When we focus on the pedagogical advantages of arts practices, the STEAM framework rejects the concept of “artsy” or “mathsy” people and instead, “places them in a context that is purpose driven, offering an opportunity for creative and flexible thinking that maps onto their key outcomes” (Bevan et al., 2019). Maker education has the potential to build some of the mutuality with the arts that STEAM aims for. However, maker educators face the same challenges that STEAM proponents do – the urge to instrumentalize making in service of accountability measures, such as science content recall or workforce development, without attention to the epistemic practices that STEM and the arts share.

A clear solution is to embrace the asset-based approach of culturally sustaining pedagogies into STEM/Maker education (Ryoo & Calabrese Barton, 2018). *Cultural making* is an approach to asset-based pedagogy that aims for a balance between respecting the local culture and context and the introduction of new elements that teachers or designers bring to the learning setting. Cultural making focuses on, “powerfully engaging youth with the political, human, and social challenges of subverting and transforming one’s reality through powerful tools and representations” (Blikstein, 2020, p. 125). Cultural making is visible in art-science projects like the Embodied Physics Learning Lab where choreography is a mechanism to both understand and represent the principles of physics through the medium of modern dance (Solomon et al., 2022). Similarly, the fiber arts can be used to teach math and computing through working with your hands to construct



representations of mathematical concepts while valuing the cultural contributions of traditionally feminine art forms (Peppler et al., 2020).

In our work, we use Critical Qualitative Inquiry (CQI) as a methodological approach that seeks to both challenge dominant research approaches, to interrupt discriminatory practices, and to work towards social justice aims (Paris & Winn, 2014; Tunstall et al., 2022). Specifically, we are inspired by Critical Indigenous Research Methodology (CIRM), as scholars who are engaged in CIRM call out the “damage-centered research” that dominates the education space and shift to “desire-based scholarship” in order to avoid pathologizing young people (Tuck, 2009 as cited in Brayboy et al., 2012).

We draw our predictions for the future of maker education from two large studies we recently conducted – one that focused on a maker-mentorship program with rural teens (Nixon, Halverson & Stoiber, 2021) and a second exploring arts practices in community youth arts organizations in historically marginalized communities (Halverson, Martin, et al., 2023). In both studies, we gathered longitudinal, qualitative data collaboratively with participants and allowed their interests and expertise to shape the conversations we had and the artifacts they generated. Three key themes are prevalent across these two studies:

1. The arts are not in service of STEM. Leveraging youth assets results in a reframing of what is valuable knowledge and expertise in makerspaces.
2. Drawing on youth’s assets highlights how cultural and technical knowing are mutually valuable.
3. Arts-practices-as-assets is broad ranging and includes longstanding, multigenerational practices and rapidly changing youth culture. Valuing this range and living in its complexities is crucial.

The next generation of maker education aims to disrupt the dominance of traditional STEM schooling goals, outcomes, and identities. Cultural making – specifically the use of arts practices as assets that young people bring to learning – can offer us a way to turn to desire-based scholarship and pedagogy and to create equitable systems on our own terms.

The future of making as a return to our roots

Kylie Peppler and Nickolina Yankova, University of California, Irvine

Anna Keune, Technical University of Munich

Sophia Bender, Nazareth Prep High School

With close links to mathematics and computing (e.g., Essinger, 2004; Taimina, 2009), historical fiber crafts present an opportune context for maker-centered constructionist learning experiences, focused on challenging domain ideas, such as unitizing within proportional reasoning. Proportional reasoning (PR), or the multiplicative part-to-whole relationship of rational quantities (de la Torre et al., 2013), has persistently challenged learners (Lobato & Thanheiser, 2002). We focus on micro-developmental learning processes within fiber crafts to examine hands-on and transformational learning for youth as they engage in personally meaningful design (Peppler, Keune & Thompson, 2020). We advance the notion of materialized action, the natural inquiry process that results through emergent patterns between learners and the materialized traces of their actions.

We ground our work in constructionism (Harel & Papert, 1991), where learning occurs best when learners design shareable physical (or digital) “objects to think with” that are at once material objects and internalized mental structures. We further draw on relational materialist views (e.g., Hultman & Lenz-Taguchi, 2010) that challenge hierarchies between people and materials, calling for lowering and even flattening such hierarchies.

Situated in an out-of-school workshop developed by crafting professionals and mathematics educators, this study takes a qualitative approach that combines design and intervention. We co-designed workshop activities to support engagement with PR through three fiber crafting traditions (i.e., knitting, crochet, and pleating). Using artifact analysis (Thompson, 2020) and modal analysis (Abrahamson, 2009), we focus on three youth as case studies to capture, analyze, and theorize how the coming-together of materials prompts hands-on and transformational learning. We first engaged with all three crafts to make sample projects toward proof-of-concept. We then drew on video data from the craft workshop and over 200 photographs of learner projects to understand how fiber crafting traditions cultivated mathematical understanding of PR.

We theorize three nested layers of units within fiber crafting. In contrast to preformed units as the basis for ratios and PR, fiber crafts afford tinkerability with units and personalization of produced artifacts. Through choice of materials and individual level of tension, the crafter forms an initial *stitch unit*. Multiplying stitch units produces *pattern units*, larger building blocks, which are reproduced to form the even larger *project units*. Unitizing within fiber crafts reflects materialized actions at play, which we observed in youths’ crafting



practices. Youth formed relationships with the domain concepts of unitizing and PR through iterative engagement with the materials as they crafted in preferred ways.

Studying relationships among materials and people within maker education can shift not only theoretical understanding of learning in context but can also impact educational practice toward more inclusive and equitable approaches within domains that are still marked by inequitable participation (e.g., Keune & Peppler, 2019). Materialized action proposes a new way of learning about units and PR as well as how to integrate (rather than exclude) worldly concreteness into mathematical practice, promising a new kind of reliability that may shift participation structures in maker settings. We predict that the future of maker education will continue and expand on these practices within and beyond mathematics, opening new possibilities for theory and practice by reconceptualizing traditional dynamics between Maker and material.

The relational, embodied and pedagogical futures of making as transformative educational practice

Shirin Vossoughi, Northwestern University

The rise of making has raised important questions around educative purposes (*making towards what ends?*), cultural processes (*the 'how' and 'for whom' of making*), and the conditions that support expansive making (*the design and practice of maker education and educator learning*) (Vossoughi et al., 2016; Barajas-López & Bang, 2018). I will share what my colleagues and I have learned about the relational, embodied, and pedagogical conditions that support making as transformative educational practice, the relationships between *making* and *worldmaking*, and some of the edges of thought that can support the future of making design and research.

I draw on critical (Freire, 1972), socio-cultural (Nasir, et. al., 2021; Vygotsky 1978) and embodied (Goodwin, 2013) theories to elucidate the pedagogical forms, axiological principles (Bang, et. al., 2016), and intentional practices of embodied relationality (Vossoughi et al., 2020) that we have found to be generative within making settings, particularly those nourishing the educational dignity and dreaming of minoritized children and youth (Espinoza, et. al., 2020). I also consider how the empirical study of making settings has contributed to our understandings of human learning and educational justice, and their emergence within moment-to-moment interaction.

Critical, ethnographic, participatory and interactional methodologies (Bang & Vossoughi, 2016; Erickson, 2012; McDermott & Raley, 2011; Paris & Winn, 2013) guide our efforts to carefully attune to the pedagogies and shifts in thinking, making and relationships with learning that emerged within two settings: the Tinkering Afterschool Program (Bay Area) and the STEAM summer experience (Chicago/Evanston). Our inquiries address the specific pedagogical forms that support expansive making and relationality, the relationships between making and opportunities for young people to engage in critical social analysis and dreaming, and the conditions that support robust educator learning.

Data sources include extensive co-authored field notes of teaching and learning interactions in both settings over the span of 3-4 years each; audio-video recordings of making interactions as well as in-depth circle-time dialogues with children and youth; interviews with students, caregivers and educators; images of artifacts in process; audio recordings of routine educator debriefs; and audio recordings of partnership meetings and co-design sessions.

Major themes that have emerged from our long-term research in these settings include:

1. The need to move beyond the binary of adult vs. child-centered education and to consider intergenerational learning, joint-activity and pedagogical artistry as key modes of justice-oriented education (Vossoughi et al., 2021);
2. The significance of moment-to-moment embodied interaction to the experience of educational dignity and expansive relationality (Vossoughi et al., 2020); and
3. The relationships between making and forms of political education that intentionally weave together critical social analysis, the imagination of possible futures and the creation of lived-in elsewheres in the here-and-now (Vossoughi, 2014; 2021).

Brief examples of each will be shared to elucidate these themes.

Looking to the next 10 years of maker education, I consider the conceptions of pedagogical design and practice that are necessary for learning environments organized around making to nurture justice-oriented forms of worldmaking with students, educators and communities (Espinoza, 2009; Kelley, 2003; Simpson, 2009).



A celebration of locally-defined making conceptualizations, technologies, and practices

Marcelo Worsley, Northwestern University

For the past ten years, many discussions about making have been dominated by a core set of digital fabrication technologies (e.g., laser cutters, 3-D printers) and a related agenda around advancing STEM education (Blikstein, 2013; Martin, 2015; Vossoughi, Hooper, and Escudé, 2016). Not surprisingly, some of the making opportunities that emerged over the past decade have been among STEM organizations eager to recast their work as new and exciting. At the same time, the field has also seen innovative organizations move outside of the normative frames and technologies of making and embraced local community values (Bodon, Kumar, and Worsley, 2022, Lee and Worsley, 2019; Shaw, Fields, and Kafai, 2019; Worsley and Bar-El, 2020). The next ten years should see more diversified forms of making and a related set of new making technologies.

This work builds on prior work around identity development (Nasir, 2002) and interest-based learning environments (Ito, 2013). Youth identity development interacts with learning and goals in ways that may show up particularly well in making experiences where youth are provided opportunities to bring their identities and interests into the learning space. Moreover, aspects of this work reflect ideas about intentionally centering minoritized identities and interests within the context of making.

Ethnography (Atkinson and Hammersely, 1998) is the primary methodology used to ground this research. The author worked as a researcher, educator, and teacher educator throughout the past 6 years in a variety of in-school and out-of-school making experiences. In aggregate, the author interacted with and observed work with more than twenty making-related organizations. Observations, student work, and field notes from interactions with students and teachers are the primary basis for this presentation.

I identify four trends that I believe will shape the next ten years of maker education. First, teachers and students have gravitated towards making activities that bridge making and student interests related to sports (Worsley, 2022), music (Bar-El and Worsley, 2019; Horn et al., 2022), fashion (Shaw et al., 2019) and games (Kafai & Burke, 2015; Maloney et. al., 2010). In many cases, participants tap into a different set of making tools (Das et al., 2020) or find novel ways to use existing technologies (Bar-El et. al., 2018). Hence, in addition to intersecting making with new disciplines, making will likely see the introduction of new (and old) tools. Second, organizations are developing bridges between making and non-western cultural practices. This observation has particularly been made in organizations in Thailand and Hawaii where students connect a commitment to protect the environment with the practices of making. Third, organizations that work with youth with disabilities are defining making in ways that resonate with their community. This involves re-evaluating the tools that are used in making and questioning normative definitions of concepts like creativity (Worsley and Bar-El, 2020). Fourth, making is becoming embedded into day-to-day learning experiences. As more pre-service teachers engage with making as part of their training, we can anticipate that they will more easily adopt making as part of their practice.

The next ten years will hopefully see making shift and adapt to a broader set of disciplines, concepts, cultures, and communities. In so doing, more of the work currently taking place along the fringes of the community might become more central.

The future of making: A robust focus on maker educator preparation

Lee Martin and Ciara Thomas Murphy, University of California, Davis

The past ten years have dramatically expanded our understanding of maker education, its potential benefits for learning and identity development, and the ways in which learning environments can be made more equitable for all learners, especially those, like women and people of color, often excluded and marginalized in such spaces. While more research is needed on all these fronts, we already know a tremendous amount about how to create good quality, equitable maker learning environments, and we have several stellar examples of such learning environments documented in the literature.

We believe the next decade of maker education research should robustly study how people learn to become maker educators. Educational reforms too often doom themselves through inattention to teachers and how they learn (Tyack & Cuban, 1995). We must build from the small but significant body of work on maker educator preparation (e.g., Harlow et al., 2018) to develop models and practices that elucidate how people prepare to work as maker educators in ways that support richly meaningful, equity-oriented making.

We discuss insights from our studies of maker educators to outline two possible areas for inquiry. We draw from studies of teacher noticing (e.g., Jacobs et al., 2010) to consider how educators can begin to see



students, materials, and learning environments in new ways. We also draw upon the idea of parallel process (Sarnat, 2019) to examine how educators relate their own experiences as makers to their role as facilitators.

Data for this presentation include interviews and written reflections. We conducted interviews with two groups of maker educators: one group reflecting on their efforts to facilitate remote making during COVID (Martin & Thomas Murphy, 2022) and another group learning about and reflecting on making and tinkering by engaging with such activities themselves (Thomas Murphy & Martin, 2022). We also draw on written reflections from undergraduates learning to work as mentors in maker education settings. We engage in thematic analysis of the whole body of interview and written reflection data (Braun & Clarke, 2006).

We identify two interrelated themes that we believe offer a fruitful addition to a research agenda on the future of maker education. First, educators' own experiences with making and tinkering provide important opportunities for them to learn to notice pedagogically relevant and meaningful features of making activities (Mason, 2002). For example, educators learn to see sticking points and avenues for resolution in a new light through their own making. Second, educators must work to transcend their own experiences as makers to see their students' experiences wholly and distinctly (hooks, 1994). Here, we see connections to play (creating non-judgmental space for personal expression) and relationship building (developing empathy and seeing others more fully). Moving beyond one's own experience is a critical move for equity-oriented pedagogies as educators work to recognize and highlight students' assets.

A focus on educator preparation will allow the field to translate findings from the past decade into better maker education experiences for young people in the next decade. This presentation contributes to an agenda for that work.

The future of making: resolving maker education's category error

Paulo Blikstein, Yipu Zheng, and Leah Rosenbaum, Teachers College, Columbia University
Richard Davis, EPFL

Though certainly not unique to this field, we propose that maker education has reached a crossroads where the multiplicity of meanings ascribed to its name, and the multiple competing historical trajectories that explain its origin, have begun to distract research and development efforts. We suggest reconsidering a taxonomy of making, crafting, and fabrication practices to more clearly delineate the modes of activity, spheres of operation, and possibilities for creativity and learning.

Taking a historical view, and analyzing the literature and non-academic documents, we investigate the history of maker education and its predecessors, to examine some critiques currently leveled against maker education. Before Make Magazine and Maker Faire imparted the Make brand on fabrication activities within educational spaces, kids were doing creative, technology-enabled projects well-aligned with constructionist principles under names like "crafts," "robotics," "tinkering," "engineering," or "digital fabrication" (e.g., Eisenberg (2002); Jeanne Bamberger's (2014) "Laboratory for Making Things" from the 1980s). Research and development on such practices worked to serve diverse and nondominant learners (Milner, 2009; Sipitakiat, 2005).

With the increasing prominence of the MAKE organization in the educational mainstream came MAKE's (now infamous) claim of ubiquity: "every kid is a maker" and, consequently, almost everything is "making." This popularization invited criticism. Buechley (2013) specifically addressed the lack of diversity and representation within MAKE Magazine's publications. Entrepreneurship was part of it, as well as a discourse of national competitiveness, pointed out by Vossoughi et. al (2016). Both researchers emphasized that communities had been "making things" for centuries, and that the "Make" brand was misappropriating the term and recasting it as something invented in Silicon Valley. Many of those critiques were directed at the branded version of the movement; but many of the previous, non-mainstream versions of "making" were doing very different types of work (e.g., Milner, 2009). That nuance was lost in translation, and the critique was generalized, glossing over the very significant differences between mainstream Making and other experiences. "Maker education" needs urgent semantic attention.

We need a new taxonomy of making practices, from industrial production to artisan-scale, that captures its multitude of goals: expression, competition, ritual, learning, subsistence. An adult crafting practical items for their home or community carries vastly different implications for equity, empowerment, and learning than do kids tinkering with robotics or an Indigenous artisan creating a ceremonial item. Referring to all these practices as "making" blurs their distinctions and dulls the generalizability of research claims about them. It also invites critiques that focus on the semantics of the term instead of looking at the empowering and agentic possibilities for learners.



In the last ten years, it has become somewhat passe to extoll the virtues of maker education—and in many cases, for good reason. But project-based, student-centered learning remains leagues better than what traditional classrooms offer. Today we have not one, but many versions of “maker education,” from the corporate, cookbook-style, and Silicon-Valley-themed workshops, to rich and complex community driven, emancipatory educational projects. In this presentation, we will bring a rich historical and conceptual documentation on the history and theories behind maker education, towards creating a conceptual taxonomy of making practices and pedagogies that can help clarify the research claims and focus of each of its versions, so that their future educational possibilities - and problems - might be better understood.

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