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Critical STEM + C Futures: Re-Imagining Equity Paths for the Next Generation of Maker Teaching and Learning STEM for All Multiplex Synthesis: November 2022

"Learning as making" in some form has been a part of STEM education for decades, as educators have explored and extolled an approach to learning that gives students agency in their learning, and situates their learning in problems, projects, and explorations that engage them with real-world phenomena (DeBoer 1991). In the wake of the rise of "maker culture" in the late 1900s (Marshall and Heron 2018, Morozov 2014), the influential "constructionist" vision of Seymour Papert and colleagues (Papert 1980), and the extraordinary proliferation of available digital tools, making has gathered strength in STEM education.

As with any educational movement that actively supports learner agency and collaboration, making also seems to open the door for a re-shaping of educational structures and values, "to sort of game change STEM education," as Dr. Justice Wallace put it. In any case, it has engendered excitement, insight, and experimentation in K-12 formal and informal STEM education, and in community STEM engagement as well. Many in the movement see potential for the transformations that making promises to be critical, in the sense of examining and challenging power structures and patterns of exclusion and inequity in STEM. Our [November Theme of the Month](#) explored the next generation of making in STEM education, and paths it may be opening to equity.

The Expert Panel

The facilitator for this webinar was [Dr. Justice Walker](#). Justice is a learning scientist and Assistant Professor at the University of Texas El Paso College of Education. For the webinar, Dr. Walker assembled an expert panel comprising [Dr. Yasmin Kafai](#), the Lori and Michael Milken President's Distinguished Professor, Graduate School of Education at the University of Pennsylvania; [Dr. Christopher Wright](#), Associate Professor of STEM Education in the Department of Teaching, Learning, & Curriculum at Drexel University; [Dr. Anja Scholze](#), the Program Director for Biology and Design at The Tech Interactive; and [Dr. Eli Tucker-Raymond](#), Research Associate Professor at Boston University's Wheelock College of Education & Human Development.

Justice offered an overview of the range of contexts and technologies that makers, including this remarkable group of panelists are exploring. He then asked the panelists to reflect on what "making" means to them currently and to describe memorable moments they have encountered.

In addressing this question, the panelists made clear that even when students encounter making activities in the context of STEM, the activities themselves cross disciplines, and challenge many conventions of schooling. Eli Tucker-Raymond described a study of literacy practices in five maker spaces, which raised the question of the connection of making to schooling. Teachers who learned about making in professional development workshops often found themselves seeing and using their disciplinary knowledge in unaccustomed and enlightening ways. This convinced them of making's potential as an educational experience — but also suggested that there would be difficulties in

incorporating making in their practice: Eli conveyed a teacher's sentiment, "We'll never be able to do this in the classroom because how are we going to get 30 students from point A to point B all at the same time?" He continued,

I realized then that it wasn't really about introducing teachers to new technologies or new ways of doing things or new tools. It was about helping them rethink what it means to teach and learn, and who can know. And so from then on, my focus in Making has been on how do we rethink relationships between educators and learners in these spaces.

Yasmin Kafai described how, in a lab school making space in which the kids were designing software, one child came to her wanting to *make* games, rather than just playing educative games. In engaging this student, Yasmin saw that the process of design opened the door to more engagement and different kinds of learning. Some of the same dynamics are at work in her current work students making electronic textiles, moving from a largely digital "microworlds" approach to making with new technologies that involves older techniques that might be labelled as "crafts," but offer rich possibilities both on their own account.

Christopher Wright talked about discoveries in a very different interdisciplinary space:

Our project aims to create and understand a model environment for young people that integrates computational making practices, thinking about STEM from an interdisciplinary standpoint in intersections with cultural and expressive practices from hip hop.

Hip hop has from its inception tinkered with (explored the potential) of sound technologies and musical ideas. This included the "integration of how math was actually used in that process to really think about what's going on. The work raises questions with far-reaching implications: What does it mean to be a maker? And then who gets recognized as such?

Finally, Anja Scholze spoke of "biomaking," in which people use a range of techniques to design with living material, in an informal-education setting. Anja, a biologist, works at a hands-on science and technology center. She spoke of how a child who'd learned to design with fungal mycelia in the Tinkering Lab later came back and sought advice about how they could incorporate fungal blocks in a robotics challenge. The child, engaged with the experience of making, easily crossed what might be seen as disciplinary boundaries (perhaps without even noticing the border), and in their inquiry drew biomaking and robotic making into collaboration in the making space. As Justice commented,

This concept of bio-making has so many implications. It means for instance, that the biotechnologies available are sufficiently robust and accessible that children can interact with organisms in ways not seen before, in ways that are creative that give to the materials and to the learner agencies we haven't seen before.

New Directions in Making

The conversation proceeded to bring out some of the frontiers in making that seemed important to the experts on the panel. Although advances in technologies bring new affordances for making, for example in biomaking or electronic wearables, the panelists directed attention to more general implications. Biomaking, for example, can engage makers with emerging science, whose possibilities for design are areas of active inquiry both in academia and industry - and in this making, their learning is truly driven by their inquiry. As Christopher said, examples like this then raise questions about what new kinds of

inquiries might emerge in the near future, and what changes that might make to the experience of making:

What might be the next inquiries? What might be the next way to think about this actual maker movement and how it can be received and also inclusive going forward?

Yasmin noted that at new frontiers, new issues of ethics and values may surface, as well: "bio-making also really elevates the questions about environmental responsibility." Eli brought up another emerging idea, which is making as a social-relational activity, in which relationships and community are products as important as the objects created on the workbench or the software environment:

Making is really about connecting with one another. And that is probably what's most important about this, it's a place for solidarity, it's a place for building relationships. It's a place for thinking about one's own wellbeing and a collective wellbeing.

Making 2.0 and Inclusion/Equity

Making is, among other things, about agency, about thinking across the boundaries of disciplines, and about connecting in solidarity and shared interest (Wallace et al. 2022). These qualities open the possibility of making as an activity, or mindset, that can foster inclusivity and equity. All the panelists emphasized the importance of seeing a making space in the context of the larger community from which the makers come, and in which they live. Indeed, it often can be that the welfare of their community is a key motivator (along with intrinsic interest) to get into making. Justice reminded us of community labs as:

spaces that are not designed to service the community in the ways we see, sometimes technology is framed, but rather spaces that are meant to be in service of the community that is reflective of its values, its needs, its priorities.

One must remember that communities have always been spaces for making — "that's part of what defines us as human beings," as Eli said. Consequently, communities have ways of doing as well as ways of knowing (two sides of the same coin), which are a deep and renewable resource, as new people find their way to making with old technologies. Anja commented:

we should learn from the past, which is just recognizing and valuing the existing or traditional forms of making craft, science, art, whatever it is, in addition to the western dominant ways of creating, thinking and knowing. ... how do we contextualize them in that way for the communities that we want to serve?

As Justice pointed out, researchers need to recognize that, in order to understand making, especially making that is situated in community (always a particular community), we need to choose research methods that preserve the richness of the context and the individuals' experiences:

Rich storytelling and understanding how people come to be in this sort of space are paramount...We don't highlight journeys enough, I feel.

The situating of making as a cultural practice in authentic contexts has potential to help teachers and others address issues of equity and inclusion. As Christopher said,

The culturally relevant part within making is considering and thinking about developing authentic relationships with communities and the young people that we're working with, and then trying to

*identify those things...What makes sense to them? What makes sense to you in that regard? And then what kinds of things can you co-create and or co-design at that moment? And so it's not about working or doing research **on** communities, but it's working **with** communities from that aspect.*

Eli added:

I think a question for us as educators and designers is, how are we parts of the communities that we're working with? What is our relationship to the people, to the children, to the adults, to the institutions of the community? I think that's something we need to consider as culturally relevant educators.... building of critical consciousness in your dialogic action. So how are we engaging learners in making the world a better place, a more just place, a more dignified place?

In turn, educators need support in building the capacity to engage with dynamic, pluralistic communities in which values are in conflict or negotiation all the time. Justice said that there is a need to:

support teachers in their ability to teach students and work through the tensions that result when "just" means different for so many people. And in public schools, our teachers are asked to serve so many who have different values, interests, and they're starting at different points, and often we don't think about what it means to not only build the relationship...but also navigate through the tensions that emerge when priorities are different.

Future Directions

A revolutionary vision, even one with mounting evidence of success, will always be in tension with current practice and structures. Future challenges for making, beyond possible new technologies or tools, are connected with systemic educational issues. Can making fit into the curriculum, which is to a considerable extent shaped by the need to define outcomes, and therefore materials and practices, which can be measured for the purposes of accountability and assessment. Making very often involves working with phenomena, materials, and processes that don't fit easily into boxes — any more than curiosity, ingenuity, and relationship-building can. Anja pointed out, for example, that design with living material is subject to the constraints of time and materials that life imposes: “things take as long as they take to grow or develop!”

Aside from the special constraints of formal education systems, it may well be that an important future development for making is to recognize the continuity between "making" as a special activity that takes place in "maker spaces" and the many kinds of making that go on in communities all the time. What can it mean for making to be truly situated in the community, and integrated into the community life?

Christopher said,

While I value my space on campus, and inviting students to come there, how do we as researchers, workers, go out into said spaces to also, again, capture, acknowledge, and then recognize the making that's happening in the moment within those spaces, as opposed to me privileging my "space on campus" as being the place where it actually happens? And so how can we make better connections between these formal spaces, per se, and again, make those connections to what's happening already in the communities.

Anja asked, from the perspective of her own work,

I'm really excited to see what doors biology as a medium can open up, just because of its inherent richness as far as its relation to us as human beings. I mean, we are biology. It relates to health. It relates to agriculture. And how can bio making be different if those are starting points and relational points for communities? And what can we build if we co-design with communities instead of this sort of biotechnology from the lab-driven, biotechnology from the sort of front edge of innovation being given to you to do something? What can we build from the ground up?

Recommendations for Researchers

Several kinds of research are suggested by this rich panel conversation.

Some studies naturally will focus on the impacts or implementation of making in a specific subject area, or with a particular population. Within the context of formal schooling, the incorporation of making presents many questions such as those raised by the panelists, for example: How is it possible to reconcile the making process with accountability systems? How does making connect with curricular standards? What sorts of teacher professional development may be needed so that teachers can best support learning in this context?

Our experts argued that making is a community process, and a community-building process. Such a view then provides a conceptual framing for questions about individual and group learning for example: how do the affordances of the technologies scaffold conceptual learning or increasing skill with the practices of science and engineering? What are the discourse practices which facilitate both the learning and the community-building?

A further range of questions may explore the formation of the maker's identity and self-efficacy, both individually and in relation to their home community, and the funds of knowledge that everyday making may offer to work in "maker spaces." Documentation and analysis of history and process will be central to understanding what is happening, how it is happening, and why: to quote Justice Wallace again: "rich storytelling and understanding how people come to be in this sort of space are paramount...We don't highlight journeys enough, I feel."

Joni Falk, PI of the STEM for All Multiplex, in her concluding remarks at the end of the webinar, highlighted a central opportunity for research on making: the formation of effective and imaginative collaborations of researchers and practitioners so they can:

really think about how making could move in different spaces, whether it's in informal settings, in after school settings or in school settings, which are certainly more challenging. And how this might change the school culture, or maybe how school culture changes to allow it. So that kind of intricate dance between culture and making.

Recommendations for Educational Administrators and Teacher Leaders

Educational administrators and teacher leaders should, early on in their thinking about making in their school context, actually participate in some making, so as to get direct experience of the culture of making, as well as the experience of being makers.

As with most innovations, school culture factors are often decisive in either enforcing the existing "grammar of schooling" and thus inhibiting experimentation, or in developing a culture of innovation, in which new practices are actively sought, tested in context by practitioners, and then adapted or

adopted. Making activities present challenges in the uses of space, time, and materials, and in time for teacher learning and collaboration, not to mention flextime for activities that cannot fit in the normal blocks of time in the schedule.

Teacher leaders with an interest in making can play an important role as pioneers, intentionally identifying possible changes in school culture to support making, and experimenting systematically with them, in collaboration with other teachers and with administrators. Here is another area in which teacher research can be an invaluable practice to adopt and encourage, both to design innovations, and to add to teachers' capacity as reflective practitioners.

References

- Deboer, G.E. (1991) *A history of ideas in science education: implications for practice*. New York: Teachers College Press.
- Marshall, J. A., & Harron, J. R. (2018). Making Learners: A Framework for Evaluating Making in STEM Education. *Interdisciplinary Journal of Problem-Based Learning*, 12(2). Available at: <https://doi.org/10.7771/1541-5015.1749>
- Martinez, S. (2019) The maker movement: A learning revolution. ISTE.org. <https://www.iste.org/explore/In-the-classroom/The-maker-movement-A-learning-revolution>
- Morozov, E. (2014) Making it: Pick up a spot-welder and join the revolution. *New Yorker*. 1/13/14.
- Papert, Seymour (1980) *Mindstorms: Children, Computers, and Powerful Ideas*. New York: Basic Books.
- Walker, J.T., Barrera, A., Sepulveda, R., & Perez-Piza, M. (2022, June). Critical Biomaking: Socioscientific Issues as Contexts for Life Science Maker Education. 2022 International Conference of the Learning Sciences Annual Meeting Hiroshima, Japan.



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