Embracing Neurodiversity In STEM
STEM for All Multiplex Synthesis: January 2023

It has long been recognized that "one size does *not* fit all" when it comes to education. Much of the debate over standards-based high-stakes tests in recent decades has been fueled by a recognition that while guidelines or standards can be designed, learners can't — and shouldn't — be standardized: Learning is a kind of growth, not a process of manufacturing. The design of learning environments and experiences too often has overlooked this crucial fact, and so learners are taught lessons about themselves and their capacities and value by systems that do not acknowledge the dynamic and diverse individuals they are. Yet by the same token, when there is a commitment to learning environments that do acknowledge human diversity, wide fields of research and innovation can open up.

While various kinds of diversities have become recognized matters of policy attention, practitioner learning, and research, educators (and others) have far to go in their understanding of the implications and opportunities presented by the remarkable neurodiversity of our species. The Multiplex's January Theme of the Month, "Embracing neurodiversity in STEM," provided a valuable entree into some innovative, design-based research being conducted by neurodiverse teams about STEM learning with neurodivergent learners in mind.

The Expert Panel
Ibrahim Dahlstrom-Hakki, a senior scientist at TERC, who has been the director of the Landmark College Institute for Research and Training, was the moderator for this Theme. The webinar panelists included Jodi Asbell-Clarke and Teon Edwards, who have worked together on several related projects at TERC, Wendy Martin from EDC, Lynn Cominsky from Sonoma State University, and Sam Tumolo of the New York Hall of Science. (See full panelist bios.) The moderator and panelists have videos sharing their project work in this month's playlist.

Neurodiversity and STEM
Jodi Asbell-Clarke provided an introduction to the concept of neurodiversity and its relation to STEM learning. The term, which originated in the autism advocacy movement, has now come into much wider use. Rather than centering on particular clinical diagnoses, it centers attention on the wide range of cognitive difference to be found in any human population. As with handedness, we are challenged to recognize that in very many cases, difference gets construed as a "barrier" or "problem" as a result of cultural factors. As Jodi said, "the barriers that students face are often a result of the environments in which they are placed and not necessarily anything that is wrong or disordered with the individual themselves."

One area in which "difference" is very often construed as "deficit" is in schooling, and STEM fields provide an interesting, perhaps crucial, arena in which to re-construe learning and neurodiversity. Research about such cognitive activities as systematic thinking, creativity, persistence, and spatial reasoning has explored how these interact with specific characteristics and capacities of neurodivergent learners. It has become clear that STEM subjects can be important areas of strength and engagement for many neurodivergent learners. In addition, the multimodal nature of STEM inquiry may have important benefits for such learners. Given this, Jodi suggested, an absorbing and productive question for STEM education is, "How do we actually leverage the talents of and also nurture the needs of neurodivergent learners so that they're no longer marginalized from STEM learning activities, but actually become central to STEM learning activities?" She outlined several areas in which neurodiversity may be salient and provide entry points for research and innovation. These included: sensory, attentional, and social differences, executive function, working memory, cognitive flexibility and inhibitory control, and planning and organization— metacognitive skills and the regulation of attention and emotion.

"Nothing about us without us."

The maxim "Nothing about us without us" has been a core value for the teams represented on our expert panel. This maxim entails a shift from historic habits of educational design, in which designers and domain experts develop materials or activities or tools *for* a particular constituency (for example, for learners on the autism spectrum, or indeed for any other sub-population). The designers may well involve representatives of the target group in testing, pilot developments, etc., but the design team retains control, as they bring to bear the kinds of good practice that typify their work.

Our panelists have come to take a different approach, which is to include people from the "target population" as full working members of the design team. This in itself is an exploratory practice, which may throw interesting new light on various aspects of cognition, communities of practice, materials design — and the construal, representation, and communication of STEM phenomena and data. Teon Edwards told us that:

> *Well over half the members of our co-design team are neurodivergent and one of the shifts we feel is really important to this work is shifting the thinking from "problems with the learners" to "the problem is with the learning environment.*

A neurodiverse team working from this point of view will see many tasks from a new perspective — "the co-design process took us to places we just didn't expect at all." For example, in the STEM game the team was co-designing, a new kind of creature was introduced, the Minos.

> *The Minos are our main alien life form in the game, bringing STEM and SAS elements together. The Minos communicate with each other via light. Specifically, they use parts of the EM spectrum that are visible to us as humans and parts that are not visible to us.*

Teon described how this species, which became a key feature of the game-world, was seen to reflect the experience of neurodivergent team members, who have "different levels of comfort with and skills with communication." Having recognized this, the Minos enabled *all* players "to experience what it meant to be bridging communication styles where the differences weren't deficits but were just differences."

Thus, the different experiences of the different team members were reified in game elements, in such a way that all players of the game are (to some degree) having a neurodiverse experience.

Lessons from STEM and Maker Programs

Lynn Cominsky spoke from the experience of NASA's Neurodiversity Network project (N3), which (in partnership with a range of other organizations) seeks to open pathways to STEM careers for people on the autism spectrum, and more generally to support STEM literacy and learning that is more accessible for autistic students, as well as professional development for teachers, based on N3's experience, and input from autistic learners and educators who work with them. Key points that Lynn raised included:

- providing a visual schedule,
- priming the students for what's to come so they understand the context and process,
- embedding their specific interests,
- establishing very clear expectations, and
- providing more visuals and videos and other reference materials

Wendy Martin and Sam Tumolo added recommendations based on their work with the IDEAS Maker program (IDEAS stands for Inventing Designing and Engineering for All Students). This is a collaborative project of the Education Development Center, the New York Hall of Science, New York University, and New York City autism inclusion schools. The project designed a maker program for all students facilitated by teachers in those schools. Maker programs have been shown to be valuable for STEM learning for students on the autism spectrum (Martin et al. 2020). The design and investigative work, driven by students' interests, provides multiple entry points into STEM content, allows students to work at a pace that enables them time to go deeply into their research or designs, work through frustrations and roadblocks, and deploy a range of strategies for successful completion. Moreover, the "making", as well as specific projects, lends itself to collaborations that arise naturally out of shared interests, tools, and materials.

While maker programs often include the use of a range of technical and digital tools, and such tools have long been seen to facilitate autistic learners' intellectual and social engagement (e.g., Weir 1987), Sam reported that in their work,

> *when we were thinking about working with elementary autistic kids, we decided that instead of introducing totally new tools and skills, we would try and draw upon the students' previous knowledge and use tools and materials that are more familiar to them and create more of an accessible entry point. So this included using things like clay, cardboard, paper. This way we communicated, 'You're already makers,' and it made it a lot more accessible.*

Thus, the environment and learning conditions conveyed messages to the students about themselves in the context of this exploratory, minds-on/hands-on program.

Another important point that emerges from this line of work (as discussed in Martin et al. 2020) is that in such maker spaces, the teacher-facilitators may well learn things about their students (including the autistic students) that are not revealed in other kinds of activities. Such activities, not constrained by the normal structures of formal schooling, can offer insight into a broad range of students' capacities — from cognitive/conceptual and communicative/social capacities to metacognitive capacities, and self-efficacy.

The Co-Design Process

Ibrahim asked, "What advice would you give educators and researchers who may be looking to incorporate co-design into their own work?"

Teon pointed out that in the development of a co-design process, it is necessary to success that the partners intentionally include a diversity of voices and perspectives as an integral part of the work. This can be very challenging and raises awareness of the presence of a range of structural imbalances (e.g., dynamics of power, expertise, status), which need to be defused if all the voices are to contribute. In such an effort, a key element is the shared expectation that diversity of perspective, if authentically embraced, will lead to better results. But there is no doubt that proceeding in this fashion is not easy:

> *It's important to be having a wealth of voices as part of the process from beginning to end.... we worked really hard to be designing the process to be making sure that the voices that were actually steering where we were going, were all being heard, and I [as a PI] worked hard to take a backseat. And that was scary. It was hard. We did things that have made my life a lot more difficult going forward, because it's like, 'okay, this is where we're going, it's not at all where I planned', and needing to make massive shifts in other parts of the work, but really exciting as a result.*

Teon raised an additional point about the collaborative work, which is the importance of what one might call attentive listening as a key strategy— especially when a challenge or puzzle arises in the course of the project:

> *a lot of it is figuring out what works for the individuals you're working with. And that should be true of any team you're working with, but it gets highlighted in a particular way when you are faced with differences that are more obvious to us when we think about, this person is neurodivergent, and I can tell that the way they're interacting with me isn't a way that I am used to.*

Wendy described how, in developing their IDEAS maker program, they wanted to develop a program that could be sustainable in schools, anchored by teacher facilitators: "we always had the teachers, the students, lead the design, because it had to work in that context, otherwise it wasn't worth having." She said:

> *We just went to the maker clubs and sat with them, talked to the teachers, talked to the students during that time, so we could really get a sense of what the experience was like. Took lots of notes and things like that. Really worked very closely with the educators as well as starting off with the administrators, because even though this wasn't a formal curriculum, it was really focused around being in the schools, not being some separate museum-based thing.*

This led to important insights about pacing, and the realization that the freedom that the maker program offered allowed the activities to proceed at a pace that was conducive to the students' and teachers' concentration and productive engagement. Sam added:

> *So something that I would do differently next time, or that I would recommend, is breaking it into smaller chunks. Do an activity, take a break, then reflect and do the co-design, instead of doing it all and then risking burnout at the end of the day*.

Finally, panelists stressed the importance of having multiple means of recording feedback. This includes allowing space for multiple ways by which students can report and represent their ideas, their data, and their findings (consonant with the multimodal nature of scientific discourse). Lynn said that in the N3 summer internship program, students presented using a variety of means:

> *You can do it live, you can use PowerPoint, you can make a poster, you can just show your poster, you can talk to your poster, you can pre-record yourself talking to your poster or talking to your slides, you can make a video. I mean, there were lots of different options. We just wanted the interns to really feel comfortable and be able to put their best show forward in terms of*

representing their work, so we were trying to de-stress it as much as possible, the presentation aspects of it.

How best to nurture the strengths of neurodivergent learners?

Our panelists offered several key responses when Ibrahim posed this question. Suggestions included:

- Putting the learner as a central participant in the learner experience, I would say is first.
- Providing autonomy of thought as part of the rhythm of collaboration: "some space to solve a problem by myself first without having to explain it to somebody else as I was solving it, because I just need that space to let my mind do the thing it does and not have to justify that or try to tie it to someone else's way of thinking. Then, once I come up with some solutions or ideas, then I'm fine collaborating, but I just need that space, that autonomy."
- Multiple entry points into an activity — as Jodi put it, "Different ways to get into a topic or to an activity may allow everybody to access it with their own strength-based perspective." Sam added: "A big part of creating a really flexible learning environment is the idea of shifting what we typically view as accommodation into choice and having basically as many choices as possible in a program...If the kids have more choice, they don't need to feel like they're incapable of doing something, they're just choosing another option. "
- Provide multiple avenues of demonstrating success, as discussed above.
- Long term mentoring for students with developing interests, which may lead towards a possible STEM career. As Lynn said, "Most scientists have mentors at some point in their career, but I think it's even more important to have a mentor that really understands just the individual differences and how to interact with individuals."

Teaching the Person

Teon brought the conversation back to a fundamental principle with tremendous practical consequences:

> *This sounds like an exceedingly obvious thing, but it isn't in practice. We need to treat all people as whole people, not just the reason someone is at the table or part of a project or a participant in a research study or something. Obviously, the reason why neurodivergent participants were such a big part of my project was that I was designing for trying to make sure that we were inclusive of those audiences, but they weren't there only as they're neurodivergent, they were there as people. Lots of them were there because they wanted to be doing game design, they were interested in science or in biology, or they wanted to be computer programmers, and this was a way to be doing that.*

Recommendations for Researchers

There is a significant need for more case material, more ethnographic data, about functioning neurodiverse communities of practice or interest.

Harvey Blume suggested once that "Neurodiversity may be every bit as crucial for the human race as biodiversity is for life in general" (Blume 1998). This is an interesting hypothesis whose validity remains to be tested in actual social settings. Researchers, including our expert panelists, have reported significant benefits to neurodivergent learners that derive from learning environments as recommended during this webinar. But much remains to be learned about the sociocultural dynamics of an authentically neurodiverse learning community: How do learners shape their collaborations? How do students of different "neurotypes" recognize and incorporate, or accommodate themselves to, the insights and *habitus* of the different "types" in the group?

When teachers learn to facilitate and support neurodiverse learners in responsively designed contexts such as maker spaces, does their pedagogy (or their understanding of their subject and its teaching) change in other contexts?

In collaborations between people from groups with different skills, interests or cultures, the tools they use or make together, or phenomena they are working on, can serve as bridges across the differences, enabling shared work and negotiation of meanings and methods. Such tools or phenomena have been called "boundary objects" (Bopardikar et al, *in press*; Star and Griesemer 1989). In what ways do phenomena, tools, or alternative methods of representation function as boundary objects to facilitate collaboration and discourse within a neurodiverse learning/inquiry group?

Recommendations for Teacher Leaders

Teacher leaders can become acquainted with the literature on neurodiversity in STEM education, starting with the resources collected for this Theme of the Month. Individually or in faculty study groups, they can examine their curriculum and pedagogy in relation to the recommendations from the expert panel outlined above. In what ways could such changes (in curriculum, pedagogy, or assessment) support all the students in their classrooms? What factors of the school culture could facilitate or hinder such changes? For example, what challenges and opportunities might arise if more of the curriculum were presented through project- or problem-based learning? Such an exploration would be very fruitful for faculties that use lesson-study or other methods for instructional improvement. Accounts of such experiments could make a valuable contribution to the educational literature and could stimulate teachers in other schools to undertake similar efforts.

Recommendations for Administrators and Policymakers

Project-based or inquiry-based science in general has encountered challenges with school cultural factors that control time, teachers' roles, collaborations with external partners, and other elements of school organization (Krajcik and Blumenfeld 2006). Administrators and policy makers could acquaint themselves with the extensive literature on these issues. They can make a positive contribution also by supporting and learning from research within their own schools (whether conducted by teacher-researchers, or by academic partners), and find ways to accommodate experimental programs that do not fit into the established schedules of curriculum and testing.

References

Blume, H. (1998) Neurodiversity: On the neurological underpinnings of geekdom. *The Atlantic*, Sept. 1998: https://www.theatlantic.com/magazine/archive/1998/09/neurodiversity/305909

Bopardikar, A., Bernstein, D., & McKenney, S. (in press). Boundary Crossing in Student-Teacher-Scientist-Partnerships: Designer considerations and methods to integrate citizen science with school science. *Instructional Science*.

Chen, YL., K. Murthi, Martin, W., Vidiksis, R., Riccio, A. and Patten, K. (2022) Experiences of Students, Teachers, and Parents Participating in an Inclusive, School-Based Informal Engineering Education Program. *Journal of Autism and Developmental Disorders* 52, 3574–3585. https://doi.org/10.1007/s10803-021-05230-2

Krajcik, J. S., & Blumenfeld, P. C. (2006). Project-based learning. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 317–333). New York: Cambridge University Press.

Martin, W., Yu, J., Wei, X., Vidiksis, R., Patten, K. P & Riccio, A. (2020). Promoting Science, Technology, and Engineering Self-Efficacy and Knowledge for All with an Autism Inclusion Maker Program *Frontiers in Education: STEM Education 19* https://doi.org/10.3389/feduc.2020.00075

Star, S. L., & Griesemer, J. R. (1989). Institutional ecology, 'translations' and boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology. *Social Studies of Science, 19*(3), 387-420.

Weir, S. (1987) *Cultivating minds: a LOGO casebook*. New York: Harper and Row, Publishers, Inc.

Written by: Brian Drayton, Co-Director for the Center for School Reform at TERC.

Copyright 2023 TERC; Funded by NSF #1922641
Opinions expressed on this site are those of the contributors and not necessarily those of the National Science Foundation.

OUR PARTNERS