International Society of the Learning Sciences

Towards Expansive and Equitable Modeling: Syncretic Modeling through the Lenses of Dance, Science, and computation

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Abstract: Modeling is a cornerstone of professional scientific practice, however, there aren't enough opportunities for youth to leverage their own perspectives when engaging in modeling inquiry. This paper describes three design dimensions—interdisciplinarity, intermodality, & intergenerationality--of a 2-week long summer camp that leveraged theories of syncretism to integrate dance, science and computing in order to support youth contributions in modeling practices. The camp engaged 12 middle school youth, 2 scientists and 3 choreographers in adopting a complex systems lens and engaging in collaborative inquiry around the scientists' research systems using choreographic and digital NetLogo modeling. Using discourse, video stills, and narrative description of a group that modeled spinal cord injuries, we show how these three dimensions disrupted barriers between disciplines (science & dance), modes of sense-making (movement & computation), and inequitable power dynamics (youth and adults). In the discussion, we draw out contributions to the literature particularly on scientific modeling.

Introduction

Modeling is central to professional science. However, for youth, modeling often takes place in classrooms where the teacher represents an epistemic authority and there are few opportunities to leverage their own perspectives. In response, there have been calls for more equitable modeling environments (Schwarz et al., 2022), ensuring that youth, especially from underserved communities, can learn from transformative environments that center youth perspectives to ultimately broaden conceptions of what counts as "science" (Philip & Azevedo, 2017; Grapin et al., 2023). These calls align with work on expansive modeling in which scholars center youth's ways of knowing and push on the boundaries of what modeling can look like (Wagh et al., 2021). In this paper, we expand on what counts as modeling by examining it in the context of a summer camp that integrated dance, science, and computation. The Dance to Explore Science program had youth of color collaborate with scientists and choreographers to model phenomena from partner scientists' research using choreographic and agent-based modeling (ABM). We draw on the construct of syncretism (Gutiérrez, 2014) to show how three dimensions—interdisciplinarity, intermodality, & intergenerationality—disrupted barriers between disciplines (science & dance), modes of sense-making (movement & computation) and inequitable power dynamics (youth and adults).

Theoretical framework

Expansive modeling

Research on expansive modeling has begun to push the boundaries of what counts as modeling by centering youth-based ways of knowing (Wagh et al., 2021). We draw on theories of syncretism (Gutiérrez, 2014) as a framework to design expansive modeling environments that draw on youth's perspectives to support new ways of modeling. Syncretism disrupts the hegemonic positioning of scientific knowledge by placing scientific and everyday knowledge practices in conversation with each other in order for new genres to emerge through the reorganization of participation structures for knowledge production (Gutiérrez, 2014).

In viewing syncretism as a design framework, we drew out interdisciplinarity and intermodality as core design principles. In terms of interdisciplinarity, we brought modeling practices from partner scientists' disciplines into conversation with choreographic practices. While choreography might not have been an everyday practice for youth participants, we drew on this discipline as a way of bringing a first person, embodied, and felt experiences into modeling (Champion, 2018). In terms of intermodality, the physical modality of dance and choreography came into conversation with the digital modality of ABM. Both modalities foreground embodied and agent-based, or first-person perspectives and the coordination of multiple moving bodies (Vogelstein, 2022; Danish et al., 2020). Choreographic modeling offered a way into an agent perspective, while digital modeling offered another perspective and scale into a complex system. A consequence of this embodied shift is that it changed the ontology of scientific models from nouns to verbs (Hall et al., 2014). Models, thus, needed to be enacted, either by an ensemble of dancers or a collection of digital agents, making thinking visible.

Equitable modeling

One goal of designing expansive modeling environments is to support equitable modeling practices that broaden who experiences and sees themselves as successful science modelers (Philip & Azevedo, 2017; Grapin et al., 2023; Schwarz et al., 2022). In connecting back to syncretism, Gutiérrez (2014) claims that bringing scientific and everyday knowledge together can support the reorganization of participation structures that "can serve as a context for possibility, ingenuity, the development of new dispositions, and for the organization of new futures" (p. 57). In our design, we conjectured (Sandoval, 2014) that the interdisciplinary and intermodal features would support the reorganization of modeling participation structures such that youth and scientists could collaborate and learn from each other, disrupting not just what counts as scientific modeling knowledge but *who* counts as knowledge producers in scientific modeling practices. From this conjecture we draw out intergenerationality as a design component. By intergenerationality we do not just mean that scientists and youth were put in a room together, as there are designs in which these interactions would entail scientists being positioned as the sole epistemic authority. Instead, we conjectured that working across disciplines and modalities that foregrounded first-person, expressive, and embodied experiences could reorganize traditional knowledge and participation structures to support equitable collaborations between youth and scientists.

Methods

Context and Participants

The Dance to Explore Science camp was a 60-hour, two-week summer camp that engaged 12 youth, 2 scientists, and 3 choreographers together in inquiry grounded in partnering scientists' research topics (e.g., cellular responses to spinal cord injuries). It was hosted at a community theater in an African American neighborhood in southeastern United States. The camp introduced participants to a complex systems lens by building choreographic and digital NetLogo models. A complex system lens implies that agents following simple rules can give rise to emergent, often unexpected, trends at the collective level (Wilensky & Resnick, 1999). In the first week, everyone was introduced to a complex system lens, which they used to deconstruct both scientists' systems into agents, rules, and emergent patterns using physical and digital modalities and representations (e.g., astrocytes are one agent in a spinal cord ecology that follow certain rules at injury sites). In the second week participants broke up into two groups (one per scientist), focused on refining and investigating questions that emerged in the first week (e.g., What do astrocytes do when there isn't an injury?) using choreographic and NetLogo modeling. This emphasized how choreographic and digital modeling can be used in conversation with each other to further scientific inquiry.

In this paper, we focus on one intergenerational group's work as an illustrative case. During the second week, Briah (9), Brandi (11), Naomi (14), and Olympia (12) collaborated with Alex and Darius (choreographers), and Francesca (scientist) to develop a model that explored Francesca's research on spinal cord injury repair. On the last day, they presented a syncretic model to an audience of friends and family which entailed running a NetLogo model as they simultaneously danced to demonstrate the cellular relationships in a healthy and then injured spine (Figure 1). The analysis for this paper works backwards from the syncretic model generated by this group (Wagh et al., 2024) to use theories of syncretic learning to better understand what might have been reorganized and how that reorganization developed to open up expansive and equitable modeling possibilities.

Figure 1

Syncretic Spinal Injury Model Presented on the Last Day of Camp

This syncretic model consisted of NetLogo code running as participants enacted their choreography, demonstrating temporal (running at the same time) and spatial (e.g., diagonal neural pathways) relationships across modalities.

Data collection and analysis

Data consisted of daily field notes, video recordings of group work and participant interviews, as well as artifacts generated from the focal group who investigated spinal cord injury repair. Our analysis focused on group-based

work during the second week when this group formed and worked backwards from the group's final syncretic model. We examined how this model developed and the observable shifts in participation structures made along the way (Gutiérrez, 2014) to ask: *How did the interdisciplinary, intermodal, and intergenerational dimensions of the camp support participation structures that opened up opportunities for equitable and expansive modeling?*

We content-logged video recordings from the second week and analyzed videos (Jordan & Henderson, 1995) of four sessions (30-90 minutes each) that tracked how this group made sense of their phenomenon, generated new ideas, and shared their work to ask a modeling question. Across these episodes we noticed shifts in the degree to which disparate disciplines and modalities were engaged with as separate or interconnected and the relationship between youth and adult contributions. In particular, both choreographic and AMB modalities afforded related but distinct ways of disrupting power in youth-adult participation structures. For this analysis, we present an empirical vignette (Erickson, 2012) of one focal episode, which demonstrates how choreographic modeling to express scientific ideas was put in conversation with other disciplines and modalities in a way that afforded youth voice and perspective to drive inquiry.

Findings

The following empirical vignette is structured around the three core syncretic design dimensions—interdisciplinarity, intermodality, intergenerationality—to show how they disrupted barriers between science & dance, movement & computation as dual modes of sense-making, and inequitable power dynamics between youth & adults, thereby creating an expansive and equitable modeling environment.

Focal episode: Foregrounding movement to represent relationships between neurons and astrocytes in a healthy spine

This group's sensemaking around spinal cord injury entailed exploring the relationships between cellular ecologies in the spine during healthy and injured states. In this focal episode, the group engaged in a choreographic exploration of the roles and rules neurons and astrocytes followed in a healthy, non-injured spine. In the analysis that follows we illustrate how each of the three design dimensions showed up in the group's modeling inquiry.

Interdisciplinarity supported new ideas as an explanation was translated into a choreographic model

This episode brought together the disciplines of biomedical engineering (science) and improvisational choreography (dance) by positioning dance as a generative way to engage in scientific modeling. It began after the group had moved into the lobby of the theater to procure a quieter space to work. In this transition, the group dispersed into four subgroups, which included some members working on their own (e.g., developing NetLogo models, writing down movement rules they had previously developed, or taking a break). The loudest and most visible activity was Francesca's conversation with Darius, in which she was explaining the roles of astrocytes in an injured state. Although Francesca moved about and used large gestures while describing her research to Darius, this interaction was primarily framed by conventional participation structures in science: an expert used verbal explanations to communicate an established understanding of a process to a novice. Francesca's explanation, however, which came with the epistemic weight of a scientist's words, was not the end of the group's modeling inquiry. Instead, this explanation was responded to with a proposal to develop choreographic rules as a way to explore a distinct, but related state: a healthy, uninjured spine. In addition, while everyone else's gaze had not been focused on Francesca, once the proposal to explore these ideas choreographically was accepted, the entire group started to participate in a way that demonstrated their implicit engagement in Francesca's explanation. The interdisciplinary dimension of this environment helped reorganize, or reposition scientific explanations as beginnings that choreographic modeling practices, driven by youth input, could explore, develop, and elaborate.

Intermodality provided multiple entry points into modeling inquiries

While engaging in choreographic modeling foregrounded physical modalities of inquiry, this group drew upon practices from the digital AMB modality as well. Participants drew on sensemaking resources valued in both the embodied, ephemeral, and felt perspectives dance can afford as well as the framing of roles and rules that an ABM lens can afford. The group focused on two ideas to explore choreographically: in a healthy spine, (1) neurons send signals and (2) astrocytes give neurons things to help them send signals, like energy. Their choreographic inquiry brought up questions and ideas that Francesca's initial explanation had not covered. For example, when the facilitator, Alex revoiced Francesca's explanation to the group, "Astrocytes in non-damaged body are giving neurons the things they need to communicate," youth participants asked important follow-up questions as they started to develop movement rules for their choreographic model: "Are they [astrocytes] just there until something bad happens?" and "What do you [neuron] do when you run out of energy?" These questions began to articulate the roles or agents in this model and the differentiated rules that governed their movements and interactions by

foregrounding youth's questions about the first person, embodied experience of dancing each role. As they continued, Alex began using language that crossed these modalities describing dancers' roles as "breeds", or classes of agents in an ABM. The intermodal dimension emphasized how the physical and digital modalities operated in conversation with each other, in this case developing improvisational dance structures that elaborated agent-based roles and rules and made both youth and scientist ideas visible for shared inquiry.

Intergenerationality supported equitable thought partnerships between youth and adults

The intergenerational dimension allowed us to see how expertise was reorganized and distributed amongst youth and adults, foregrounding how youth ideas and perspectives spurred the group's choreographic modeling and how adults were positioned as collaborators and not gatekeepers of knowledge. As the group started to move together, they began to clarify the rules for each role, such as what it meant to send a signal as a neuron (Figure 2), the way neurons demonstrated their energy state, and how astrocytes physically gave neurons energy through support (Figure 3). Some ideas were shouted out verbally by youth, like when Briah suggested that each neuron send four signals before powering down or when Olympia suggested that the neuron movements were, "getting weaker […] bigger to smaller" to show a decrease in energy. Other ideas were shared physically, such as Naomi adding a direction to her interpretation of a signal pathway as a neuron (Figure 2D) or Olympia physically lifting up Francesca's shoulders to show how astrocytes could use supportive movements to give a neuron energy (Figure 3). Alex built on Olympia's movement proposal by sharing a choreographic game called "sculptor clay." Even though Alex was the adult facilitator, he gently offered this idea as a proposal, and not a direction. The youth accepted this proposal and incorporated the game into modeling how neurons communicate signals. The intergenerational dimension disrupted presumed power dynamics as adults and youth engaged in an equitable collaboration in which participants each brought unique perspectives to the group.

To summarize, this focal episode illustrated how choreographic modeling provided a medium for youth participants to grapple with and interrogate a professional scientist's verbal explanation in ways that leveraged the dual modalities and intergenerational assets available in this space.

Figure 2

Choreographic Modeling Exploration of Neurons Sending Signals

Three neuron dancers used mirrored movements to pass a from Francesca (4A) to Alex (4B) to Naomi (4C-D) who extended the mirrored movement to show the direction the signal was moving in (4D).

Figure 3

Choreographic Modeling Exploration of Neuron & Astrocyte Relationships

As an astrocyte giving support and energy to a neuron, Olympia moved Francesca's shoulders (left image) so that Francesca was in an upright position (right image).

Discussion and conclusion

We build on modeling literature that has shown that learners' resources can play a generative role in scientific modeling (e.g., Lehrer & Schauble, 2005; Wilensky & Reisman, 2006), and that integrating multiple modalities for scientific modeling can support learning (e.g., Manz & Georgen, 2023; Pierson & Brady, 2020). One of our key contributions is that we characterize how it can also disrupt disciplinary boundaries, modes of sense-making, and inequitable power dynamics to position adults and youth as collaborative thought partners. The latter is in contrast to the literature in scientific modeling in which, at best, the adult (teacher) is a facilitator who elicits and builds on student ideas (Swanson et al., 2024; Wagh et al., 2024). Our hope is that collectively, these three dimensions as instantiated in this camp can inspire new visions for what expansive and equitable modeling can look like and offer for in- and out-of-school environments.

References

Champion, D. N. (2018). *The STEAM dance makerspace: A context for integration: An investigation of learning at the intersections of STEM, art, making and embodiment* (Doctoral dissertation, Northwestern University).

Danish, J. A., Enyedy, N., Saleh, A., & Humburg, M. (2020). Learning in embodied activity framework: A sociocultural framework for embodied cognition. *International Journal of Computer-Supported Collaborative Learning*, *15*, 49-87.

Erickson, F. (2012). Qualitative research methods for science education. *Second international handbook of science education*, 1451-1469.

Grapin, S. E., Pierson, A., González-Howard, M., Ryu, M., Fine, C., & Vogel, S. (2023). Science education with multilingual learners: Equity as access and equity as transformation. *Science Education*, *107*(4), 999-1032.

Gutiérrez, K. D. (2014). Integrative research review: Syncretic approaches to literacy learning. Leveraging horizontal knowledge and expertise. *63rd literacy research association yearbook*, 48-61.

Hall, R., Ma, J. Y., & Nemirovsky, R. (2014). Rescaling bodies in/as representational instruments in GPS drawing. In *Learning technologies and the body* (pp. 112-131). Routledge.Miller, Manz, Russ (2020)

Jordan, B., & Henderson, A. (1995). Interaction analysis: Foundations and practice. *The journal of the learning sciences*, *4*(1), 39-103.

Lehrer, R., & Schauble, L. (2005). Developing Modeling and Argument in the Elementary Grades. In Understanding Mathematics and Science Matters. Routledge.

Manz, E., & Georgen, C. (2023). Interlocking models in classroom science. *Science Education*, *107*(6), 1399-1434.

Philip, T. M., & Azevedo, F. S. (2017). Everyday science learning and equity: Mapping the contested terrain. *Science Education*, *101*(4), 526-532.

Pierson, A. E., & Brady, C. E. (2020). Expanding opportunities for systems thinking, conceptual learning, and participation through embodied and computational modeling. *Systems*, *8*(4), 48.

Sandoval, W. (2014). Conjecture mapping: An approach to systematic educational design research. *Journal of the learning sciences*, *23*(1), 18-36.

Schwarz, C. V., Ke, L., Salgado, M., & Manz, E. (2022). Beyond assessing knowledge about models and modeling: Moving toward expansive, meaningful, and equitable modeling practice. *Journal of Research in Science Teaching*, 1086-1096.

Swanson, H., Lawrence, L., Arnell, J., Jones, B., Sherin, B., & Wilensky, U. (n.d.). Computational models as tools for supporting for responsive teaching. *Behaviour & Information Technology*, *0*(0), 1–18.

Vogelstein, L. (2022). *Choreographic ways of knowing as generative site for STEM learning, design, and analysis* (Doctoral dissertation, Vanderbilt University).

Wagh, A., & Dickes, A. (2021). Expansive Modeling: Broadening the scope of modeling in K-12 education. Annual meeting of the International Society of the Learning Sciences, 2021, 827-834.

Wagh, A., Rosenbaum, L., Fuhrmann, T., Eloy, A., Blikstein, P. & Wilkerson, M. (In print). Towards ontological alignment: Coordinating Student Ideas with the Representational System of a Computational Modeling Unit for Science Learning. *Accepted for publication to Cognition & Instruction.*

Wagh, A., Vogelstein, L., & Champion, D. (2024). Fused Representations: Linking Choreographic and Digital NetLogo Modeling through Intermodal Inquiry. In *Proceedings of the 18th International Conference of the Learning Sciences-ICLS 2024, pp. 714-721*. International Society of the Learning Sciences.

Wilensky, U., & Reisman, K. (2006). Thinking like a wolf, a sheep, or a firefly: Learning biology through constructing and testing computational theories—an embodied modeling approach. *Cognition and instruction*, *24*(2), 171-209.

Wilensky, U., & Resnick, M. (1999). Thinking in levels: A dynamic systems approach to making sense of the world. *Journal of Science Education and technology*, *8*, 3-19.

Acknowledgments

This material is based upon work supported by the National Science Foundation under Grant No. 2115773. We would like to thank the youth, scientists and choreographers who participated in the Dance to Explore Science camp. We would also like to thank our research assistant who supported data collection and organization efforts. We are indebted to the generous and insightful contributions of our design team: Curtis Thomas, Rebecca Steinberg and Lara Appleby, without whose brilliance this work would not be possible. Lastly, we want to note that all three authors contributed substantially to the ideation and writing of this paper.