International Society of the Learning Sciences

Embodying STEM: Learning at the Intersection of Dance and STEM

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Abstract: This symposium addresses dance as a site for STEM learning. We present papers from five research projects that each sought to engage youth in embodied STEM learning using dance, exploring the power of creative embodied experiences and the body's potential as an expressive tool and resource for learning. We show how dance activities expanded access to STEM and supported sense-making; how dancer and dance-making practices were leveraged to support computational thinking, modeling, and inquiry; and how moving bodies in creative ways helped to generate new insights by allowing for new perspectives. Across our work, we seek to understand the multiple, rich learning opportunities that emerge from working across the arts and sciences, dance and STEM. Together our research shows that attending to opportunities for STEM engagement and learning through dance practices can broaden access to learning and engagement in STEM for all.

Session overview

"We want to dig down deeply in understanding movement as a site of knowledge, so that dance is placed at the center rather than the periphery of interdisciplinary dialogue"
- Norah Zuniga Shaw, Synchronous Objects Project

The notion that thinking is an "embodied" activity, that the active human body as a whole, not just the brain, is involved in how we conceptualize situations, has been developing for decades in the writing of philosophers, cognitive and learning scientists (Merleau-Ponty, 2002; Lakoff, 2012; Varela, Thompson, & Rosch, 1991; Goodwin, 2000; Streeck, Goodwin, & LeBaron, 2014). However, embodied cognition literature has yet to explicitly address movement as a creative, cultural, and expressive medium. A notable absence of thought remains around ideas of the body and bodies as conversational and expressive, and a particular gap exists when it comes to STEM learning through creative-expressive-embodied dance activities. Each paper in this symposium contributes to a collective re-conception of STEM embodiment by focusing on how youth use expressive movement to engage with ideas as they explore STEM in formal and informal learning environments.

Embodied cognition in the learning sciences has focused on important work in which body movements augment technological environments to support deep disciplinary learning. Rooted in gesture studies, this work situates intuitive embodied experiences as a developmental beginning towards internalizing concepts cognitively (Abrahamson & Lindgren, 2014). We offer an alternative framing of embodiment where the expressiveness of full-bodied coordinated movements themselves are the means and ends of learning (Marin et al., 2020). This new framing of embodiment allows us to see dance as a medium for engaging in STEM-based inquiry. Dance invites us to move in solidarity with one another, exploring our world through our whole bodies and our whole selves, the cognitive, creative, emotional and the logical. It affords multiple ways of bodily knowing, access to multiple perspectives, as well as physical, emotional and affective stimuli, and dance practices can be valuable resources for inquiry and problem solving. The challenge of *Reflecting the Past and Embracing the Future* extends to us the opportunity to understand STEM learning as it is and imagine it as it could be, as creative and embodied.

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Through this symposium, we invite participants to explore the power of creative embodied experiences and of the body's potential as an expressive tool and resource for learning. We hope to engage in a broader conversation about embodiment by sharing data that shows how dance activities can expand access to STEM and support STEM sense-making; how dancer and dance-making practices can be leveraged to support computational thinking, modeling, and inquiry; and how moving bodies in creative ways can help to generate new insights by allowing for new perspectives. We have organized the presenters temporally, working from 2017 up through 2020 when the global COVID pandemic upended our ability to move in co-present spaces, as we acknowledge how the virtual re-mediation of our lives has impacted our understandings of the body now and for the future. The symposium will be organized as follows: (1) co-chairs will lead an embodied warm up to contextualize issues across projects (5 min); (2) each project will present (12 min); (3) the co-discussants will pose questions and implications across the collective work (10 min); (4) we will take questions from the audience (15 min).

Dance/Making: Integrating STEM and arts across 3 dimensions

Dionne Champion, University of Florida

Dichotomous ways of thinking that privilege science over art, thinking over doing, the immaterial over body and logic over emotion or creativity have led to narrow perceptions of science as disembodied, emotionless, objective, and lacking creativity (Bowman, 2004; Brickhouse, 2001) and to equally narrow perceptions of art as frivolous, irrational and non-cognitive. Despite research that has begun to recognize the value of learning at the intersection of science and arts and of embodied science learning (Johnson-Glenberg et al., 2014; Abrahamson & Lindgren, 2014; Root-Bernstein et al., 2011), there have been few studies focused on understanding dance as a creative-expressive-embodied resource for STEM problem-solving and sense-making.

This paper explores dance as a resource for STEM learning in the dance makerspace, a 4-week summer program that challenged youth (ages 9-14) to engage in dance/Making, a process of making with movement, materials and bodies. Youth in the dance makerspace choreographed projects that explained science phenomena using movement and music, physical and computational tools, kid-friendly electronic elements (i.e. LED lights, Arduino boards, conductive clay), and other materials. The design-based research intervention was developed to explore the affordances of dance as an interest, a creative practice, and a way of knowing and to explore the relationships between "making to learn" and movement and dance for African American youth who often experience marginalization around science and technology and end up positioned as disinterested in science.

Utilizing a lens of representational mediators and practices (Danish et al., 2007), video data from the 4th and final iteration of the study was analyzed to understand how youth drew on STEM practices to inform their creative dance/Making process and how the process of dance/Making expanded their engagement with science and technology. Findings show that the process of dance/Making supported interdisciplinary problem solving, sense-making and sustained science inquiry. The following example featuring one project group, *Stardust* (a group of five girls who developed a choreographic representation of Saturn), demonstrates three ways that youth blended artistic and scientific practices to support science sense-making: integrating dance and technology to develop their choreographic explanations, developing an integrated art/science practice of modeling (Enyedy et al., 2014; Root-Bernstein et al., 2011), and combining narrative and analytical ways of thinking in their choreographic explanations (Bruner, 1987).

Dance and Technology. To develop a choreographic explanation of the formation of Saturn, its rings, and Roche limit (the invisible barrier around the planet; the minimum distance at which an object can approach without being disintegrated), Stardust created a representation that used dance and technology to highlight many essential ideas. They designed and constructed a foam model of Saturn mounted on a rotating electric motor with LED light dust and ice particles. They used dancers to play the role of gases and heavier elements drawing together under the force of gravity to form the planet and its Roche Limit. They utilized technology to enhance the ideas they articulated with their bodies (representing the particulate nature of the rings with LED lights while representing orbit with movement); interacted with it as a prop to help explain the phenomenon (spinning model of Saturn as the planet); and integrated it into their movement phrases ("becoming" Saturn as a way to switch the motor on). Embedded in their attempt to bring their choreographic ideas to life were design conversations that required them to attend to and understand the technologies they wanted to employ (e.g., how to wire and power the LED lights and fan motor needed to represent ice and dust particles of Saturn's rings). Their representational choices reflected their understanding of the phenomenon and offered opportunities to develop technical skills related to engineering, circuitry, and design through the dance/Making process.

Blending Art and Science Practices. To create their project, Stardust engaged in the practice of modeling; however, this practice could not be defined as simply science, engineering, or art because it integrated science, engineering and art. It was a STEAM making practice that involved exploring science ideas using both STEM

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and arts as tools for making and investigation. Modeling as a dance/Making practice served a variety of purposes. The girls made models to provide inspiration for choreography, to brainstorm new ideas, develop prototypes, solve problems, figure out technical design features, work through their developing understanding of the scientific explanation of the phenomenon, and to represent aspects of planet formation in their final representation. They tried many different choreographic ideas as they thought through the best way to model the formation of Saturn's rings, embodying the objects that approach the planet and disintegrate into particles that would form rings. Modeling the phenomenon and iterating on their ideas impacted how they thought about the phenomenon, offering opportunities to experience aspects of it from multiple perspectives, and about the representational possibilities by prompting discussions about which features of the phenomenon were essential and which could be left out of their final representation.

Narrative and Analytical Ways of Thinking. As the girls began developing project ideas, they researched the process of planet formation as a way to inform their choreography. Their research raised new questions and new directions for exploration and provided opportunities to become familiar with the symbols scientists used to describe the phenomenon, which led to new knowledge that they used to make representational decisions. Science supported storytelling through dance, and the act of developing a narrative was a tool for understanding the science. In dance, narrative is a tool that can be used to structure the development of choreographic compositions (Wright, 2003). It allowed for flexibility in storytelling and the simultaneous exploration of multiple ideas. The girls used their choreography to simultaneously explain processes, causes and effects, and relations among aspects of the phenomenon, all placed within the context of a story about the formation of the planet. Dance in this context became a representational medium for both narrative and analytical (or paradigmatic) thinking, providing rich opportunities for integration of these explanatory approaches.

Dance/Making using materials, tools, and bodies to express and support their developing understanding of phenomena created opportunities for youth to shift how they engaged with and understood the science they studied. Youth explored science content and experienced STEM practices in the context of dance/Making, and as a result, were pulled into science phenomena in ways that became personally and physically engaging. This work has the potential to broaden and expand how we think about STEM learning by identifying ways in which embodied creative processes like dance/Making can be resources for science learning and ways that STEM can be a resource for creative thinking. This is critical for understanding learning in informal creative spaces, learning driven by movement, and learning for populations for whom movement and the body are valued cultural resources.

Exploring opportunities for embodied learning in dance/STEM with black girls

Folashade Solomon, TERC

The notion that thinking is an "embodied" activity – that the active human body as a whole, not just the brain, is involved in how we conceptualize situations – has been developed in the writing of philosophers such as Maurice Merleau-Ponty (2002) and of cognitive scientists such as George Lakoff (2012). Other researchers developing the field of embodied cognition have used evidence from linguistics, psychology and cognitive science-among other fields-to argue that all human cognition is embodied action (Lakoff & Johnson, 1980, 1999; Varela, Thompson, & Rosch, 1991). These researchers argue that both our most simple conceptualizations and our most complex problem solving are influenced by our bodies and are enacted in constant interaction with our physical environments. Building on this work, anthropologist Tim Ingold argues that whole body movement has not been deeply explored in the literature on embodied cognition and suggests that dance is an important type of embodied cognition (Ingold, 2011). Our paper explores the ways in which dance is a type of embodied cognition as well as an art form and affords access to cultural practice. The importance of dance in Black culture positions the artform as a site of rich identity and confidence for Black girls. In this paper, we examine the role of dance as an embodied resource for physics learning and explore how this culturally and personally expressive medium can expand access to physics for Black girls. We look closely at youth interactions in the Embodied Physics Learning Lab (EPLL), a program that invited 15 Black high school girls from two community-based dance centers to engage in embodied activities that combined dance and dance-making practices with physics to better understand how interdisciplinary approaches present opportunities to enhance engagement, provide additional lenses for meaning-making, and foster meaningful connections to physics.

We engaged in an iterative process of design, observation and analysis of the Embodied Physics Learning Lab, utilizing design-based research (DBR) (Cobb et al., 2003) and responsive design approaches to design the lab and qualitative interpretive methods to understand participant perspectives and experiences (Denzin & Lincoln, 2008). Building on sociocultural perspectives, we designed an environment that recognized, respected and recruited youths' prior knowledge, cultural identities and practices to engage them in the study of physics. There are few studies that look at STEM learning environments, embodiment, and identity with underserved

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students. It is here that we situate our work - at the intersection of dance and informal science learning and identity studies primarily involving Black girls.

This paper focuses on project findings that show different uses of embodied learning in Dance/STEM to explore scientific phenomena. We share three types of embodied learning activities that enabled physics engagement and inquiry among teens in the learning lab as they used their bodies to think, investigate and model physics concepts and ideas: embodied imagining, kinesthetic experience and re-presentation. Embodied imagining involves exploring physics content through dance-making structures and practices; for example, engaging in sense-making through improvisation and imagery, (i.e. mobilizing dance to animate concepts in particle and quantum physics). Kinesthetic experience involves sense-making through one's own bodily experiences (i.e. exploring gravity's effect on your one's body by jumping while being lifted). Re-presentation, as defined by Champion (2018), involves interpreting, combining, reformulating, and translating ideas that were researched and collected about a phenomenon to create a new representation to re-present it in a new embodied form. Through a close analysis of the resources youth drew from in their interactions in the Embodied Physics Learning Lab, we show that movement, bodies, emotions and culture can be rich resources that, while sometimes seen as deficits, can be useful in supporting understanding and engagement with physics ideas. We argue that when repositioned as strengths, dance practices can act as powerful funds of knowledge for accessing these resources, giving Black girls new paths forward into physics.

Traditionally, physics is too often presented as a set of abstract and disembodied concepts. Engaging youth in learning approaches that leverage embodied sense-making allows them to use a fuller set of meaning-making resources to understand ideas, formulate descriptions, and express their understandings. Non-traditional forms of participation can encourage all students, especially those who might not otherwise participate, to enter academic conversations (Ballenger, 1997; Varelas, et.al., 2010; Warren & Rosebery, 1996). This work offers approaches for fostering more effective participation of underrepresented populations in art-based learning and STEM fields.

Dance as scientific inquiry: How does improvisational movement support collaborative sensemaking for young children?

Lindsay Lindberg, UCLA & Noel Enyedy, Vanderbilt University

Despite the growing momentum behind the STEM to STEAM (STEM + Arts) movement in K-12 education (Maeda, 2013), dance and other body-based artforms are rarely considered part of canonical science learning. However, research shows that dance adds a distinct layer of sense-making tools with which students and scientists can make sense of multidimensional scientific phenomena with their bodies (Ochs et al., 1996; Nasir, Rosebery, Warren, & Lee, 2006; Myers, 2012). Previous work has addressed using dance as a tool to represent already-learned knowledge (Zohar & Abrahamson, 2015; Myers, 2012), but those studies run the risk of discounting the role that active dance-making can play in supporting science sense-making. Rather than positioning dance as solely "an instrument for science communication" (Myers, 2012 p. 159), this analysis positions young science learners using their bodies and dance as "experimental media to generate insight into molecular forms" (Myers, 2012 p. 172). This analysis builds on the Learning in Embodied Activity Framework (LEAF) (Danish et al., 2020), and positions dance as a discipline and culturally specific practice that is distinct from, and intentionally supports collaborative science learning.

This analysis is part of a larger, multi-year design based research study (Design Based Research collective, 2003), iSTEP (Interactive Science Through Technology Enhanced Play). The project focuses on the ways in which young children (ages 6-7) engage with science learning in an embodied mixed reality setting through inquiry and embodied play (Danish et al., 2020; Enyedy et al., 2015). A seven-day unit explored particle behavior of both micro- and macro-states of matter using OpenPTrack technology which tracked students' speed and location, and communicated that to a projected simulation. Throughout the intervention, students learned that particulate matter in a solid moves slowly (vibrates in place), liquid particles move at a medium speed, and gas particles move quickly. This analysis looks closely at video data from the seventh and final day of data collection, wherein groups of four students choreographed and performed dances representing a state change (i.e., from liquid to gas). Using inductive methods and interaction analysis (Jordan & Henderson, 1995), we track the choreographic process and embodied activities of one group of 4 students and 1 researcher representing a state change from liquid (water) to solid (ice).

Our analysis demonstrates the multiple ways students make sense of and represent a scientific concept-water particle behavior as a liquid. Throughout the choreographic process, students' verbal descriptions of particulate behavior remained stable, while their movements demonstrated nuanced explorations of water particles in a liquid form. They generated and iterated movement ideas nine times over two minutes, representing particles

while moving at both a medium speed and at a medium distance away from each other. Students used levels in two ways (standing high on tiptoes, squatting low towards the floor) to explore ways that particles could be standing in the same place "medium" distance apart. This analysis shows students using dance as one way to deepen their engagement with the science material, not to merely represent their already sealed canonical content knowledge about states of matter. Indeed, the process of choreographing scientific ideas, even when students have previously embodied the phenomena as a group, involves opportunities for new noticings that support learning. Dance is not simply a tool to present previously learned knowledge, but an opportunity to deepen understanding of canonical science content.

Students used multiple bodily movements and positions to represent the same verbal descriptions - "medium" speed and distance from each other. This matters because by limiting what we recognize as canonical science, we miss out on nuance that students pick up, embody, and express while engaged in dance as a sense-making process. This analysis shows students applying their embodied science knowledge to their choreographic processes, furthering past research that positions dance performance as a tool for students to develop their sense-making and argumentation around science (Lindberg et al., 2019). Dance added affective and embodied depth to the students' conceptualization of the canonical science knowledge, which is worthy of future investigation.

Developing computational double awareness through rule-based dance games

Lauren Vogelstein a ndCorey Brady, Vanderbilt University and Rebecca Steinberg and Curtis Thomas, Independent Dance Artists

Professional dancers' execution of choreography entails that dancers understand both how it feels to execute movement from within an ensemble of moving bodies and what the entire ensemble looks like to an outside viewer. This phenomena, referred to by dancers as "double awareness," gives dancers an intrinsic perspective from within while maintaining an extrinsic perspective without being an outside viewer. In this paper we explore how the practices of professional dancers can be leveraged for middle schoolers to develop a double awareness of computational agents by engaging together in rule-based dance games. This speaks to the importance of taking multiple perspectives in learning about the computational components of complex systems (Olson, 2015; Papert, 1980; Wilensky & Reisman, 2006; Wilensky & Resnick, 1999) and expands it through design based research (Design Based Research collective, 2003) that leverages the expressive practices of professional dancers engaging their whole bodies in movement together (Vogelstein, 2020).

This work reports on the design process and implementation of a one-week art and coding camp for middle schoolers. The camp was co-designed by the authors (one learning scientist and two professional dancers) and four math teachers with a goal of leveraging mathematical and computational connections between choreography and programming in an agent based modeling environment (NetLogo). Video recordings of designing and implementing the camp were analyzed using Interaction Analysis (Jordan & Henderson, 1995; Hall & Stevens, 2015) to explore the micro and multimodal nature of sense-making in interaction.

As an art and coding camp, our goal was for students to explore the expressive potential of computational environments physically and digitally. The soup game, a rule-based dance game suggested by Steinberg & Thomas, provided campers the opportunity to develop choreography quickly as an ensemble while co-developing an understanding of computational concepts (e.g. code specificity, agent interpretation, procedures, and conditional statements). Setting up the game involved campers creating a set of rules to follow (e.g. Rainbow Muffins meant everyone walked forward a random number of steps less than 21 in whatever direction they happened to be facing at that moment). Playing the soup game involved freely moving about until an outside leader called out a rule that was then instantly followed. When campers developed rules they had to show players what it meant to follow it. This raised important questions from peers about specificity, asking questions like "How long do we wiggle for?" or "How many steps forward do we take? Are they in a certain direction?" These calls for specificity exemplify the role that double awareness played in the campers' understanding of both activities--writing and interpreting code as well as choreographing and being choreographed for. These noticings stemmed from students taking the perspective of what they as human agents/dancers would have to enact in the game, while responses took into account what it would mean for an individual to enact a rule and what the group might look like enacting this rule together. As campers played the soup game over the course of the week the complexity of their rules and ability to enact them as an ensemble visibly increased as their double awareness developed and supported their computational fluency.

Through this work we are beginning to understand how an experience of being inside a structure and forming it in relation to others supports new understandings of the structure itself. Based on these findings, we argue dancers' engagement in double awareness can be leveraged for computational learning, supporting students' understandings of the expressive potential of computation.

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DanceON: Exploring embodiment in a dance computing learning application

Kayla DesPortes, William Payne and Yoav Bergner, NYU

Computing technology presents opportunities to examine the ways in which data on and about the body can be sensed, represented, and interacted with to support dance practices while also supporting learning about computing. Dance education engages learners with their physical, intellectual, and emotional selves (Bannon, 2010) while providing practices tied to "self-expression and interpretation through motion" (Koff, 2000). Developing learning experiences across computing and dance enables us to examine how we can leverage embodied ways of knowing about the self and computing technology grounded in our understanding of our perceptual representations and bodily states within a social environment (Lawrence, 2008). In this research, we examine how computing technology can be designed for a dance computing educational environment to diversify the embodied ways of knowing and learning.

Prior work at this intersection has examined the potential for learners to leverage knowledge of their bodies as they problem-solve and program virtual avatars (Leonard et al., 2020). For example, Leonard et al.'s work explored the idea of body syntonicity (Papert, 1980) as they identified how some learners approached a challenge of programming a virtual avatar to dance through moving their real bodies and translating the knowledge from physical movement into code (2020). We build on this work exploring opportunities for embodiment in a dance computing tool called danceON (dance Object Notation) (Payne et al., *In Press*).

We developed danceON through a collaborative design-based research investigation (Design Based Research Collective, 2003) consisting of semi-structured interviews and weekly design meetings with STEM From Dance, a community organization that specializes in developing computing experiences for young women of color to expose, interest and engage them in STEM disciplines. The technology was developed in the midst of the COVID-19 pandemic, thus developed in ways that aligned with the need to engage with learners in a remote environment. danceON pairs a declarative, reactive programming environment (Krishnamurthi & Fisler, 2019) with built-in pose detection. The system enables learners to program animations that respond to the pose data of their bodies. These animations are then rendered on top of a coordinate pixel plane of their uploaded video data or webcam footage. Through this integration of body data, the learner's own movement and position become the subject of most programming statements in danceON. Thus, common programming constructs are embodied and reasoned through with movement. For example, learners can trigger animations based on conditional statements that explicitly describe body positions, e.g. "if my left wrist is in the top left position of the screen", "if my right knee is above my right hip," etc. Literature on embodiment suggests the importance of being able to ground the meaning of words and actions into the lived experience of the person (Glenberg, 2008).

We discuss our findings from an analysis of four artifacts created with danceON that encompassed music videos with original choreography and programmed animations, co-developed by learners and instructors within a STEM From Dance summer camp. The artifacts encompassed themes related to girl power, the Black Lives Matter movement, and self-love. We reflect on the ways the code represents how learners were able to explore body position and movement within their creations and examine how computing technology could further support embodied learning experiences and expressivity. Our analysis demonstrates how learners were able to: (1) identify, quantify, and define specific movements and poses; (2) explore mappings of animations to their bodies; (3) augment choreography with animations that represent specific lyrics and visually convey narrative; and (4) experience and overcome the affordances and constraints of computer vision algorithms that occasionally produce missing or inaccurate data.

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