Broadening Learning Sciences Theoretical Lenses to Understand Young Children's Sensemaking

Danielle Keifert (chair), University of North Texas, danielle.keifert@unt.edu
X. Christine Wang, State University of New York at Buffalo, wangxc@buffalo.edu
Dania P. Sacks, University of Haifa, daniaura1985@gmail.com
Sharona T. Levy, University of Haifa, stlevy@edu.haifa.ac.il
Xintian Tu, Indiana University, tuxi@iu.edu
Joshua Danish, Indiana University, jdanish@indiana.edu
Megan Humburg, Indiana University, mahumbur@iu.edu
Noel Enyedy, Vanderbilt University, noel.d.enyedy@vanderbilt.edu

Ananda Marin (discussant), University of California at Los Angeles, amarin1@g.ucla.edu

Abstract: If "the theories that we propose and the assumptions that we hold fundamentally shape the questions we ask, what we notice, and what we design for" (ICLS Call for Papers), we must understand the full diversity of human learning, including critically the learning of young children (ages 5-8). This session explores how several scholars have applied and pushed for revisions of existing theories as the Learning Sciences field seeks to better understand young children's sensemaking. Each paper takes up two central questions: (1) How is existing LS theory drawn upon in each study? (2) How is new theory built or existing LS theory modified in each study? The goal of attending to these questions is that participants in this symposium might better understand the ways that existing theory does and does not work when studying young children.

Session overview

As stated in the call for papers, "The Learning Sciences, as a field, has historically focused on interdisciplinarity—to center learning as a phenomenon and interrogate it with different lenses." These lenses of course include methodological approaches. But, as a field dedicated to building theories of learning, these lenses must also include conceptualizations of practice—how people engage in shared activity to understand the world around them in valued ways within particular communities (Nasir et al., 2006)—and epistemic reasoning—what people come to understand about knowledge and knowing process. These are central lenses in the study of how people make sense of the world, and in what ways they organize that understanding.

Although the Learning Sciences is a diverse field representing many different methodological approaches, very little of the work presented at the International Conference of the Learning Sciences has historically examined the learning of children under the age of 10 (Koh, Cho, Caleon, & Wei, 2014). As a field dedicated to building theories of learning, this is a problematic oversight for two reasons. First, any exclusion of particular populations of people limits the robustness of theories describing the practices and epistemologies that shape human learning and knowing. A significant potential consequence of this lack of robustness includes a tendency to produce pejorative representations of children rather than demonstrate their competence (Vossoughi & Gutiérrez, 2014). Second, any development of theories and designs in the learning sciences should be positioned to serve all learners, not just those currently represented in the field. This is critically important as more researchers and educators draw upon Learning Sciences research to inform learning designs for young kids.

If it is true that "the theories that we propose and the assumptions that we hold fundamentally shape the questions we ask, what we notice, and what we design for" (ICLS Call for Papers), we must understand the full diversity of human learning, including the learning of young children. To begin the work of exploring how existing lenses of epistemology and practice may be drawn upon in research, we bring together four different approaches that share overlap in our focus on the central idea of understanding children's sensemaking. Each study makes the assumptions that "kids make sense" (McDermott, 1977) and the role of researchers is to better understand how children are working to make sense of the world. However, each study examines the shared lens drawing upon a set of common conceptual ideas in the Learning Sciences. Table 1 (below) illustrates the ways in which these four papers attend to epistemology and practice in their work with young children (ages 4-8 years). Wang, Tu et al., and Keifert examine inquiry as a practice, with both Tu et al. and Keifert drawing also upon other familiar practices of young children. Wang & Keifert attend to inquiry engagement as a window into young children's epistemology, while Sacks & Levy and Tu et al. draw upon complex systems as a central focus. Through these overlapping, but distinct, approaches to studying young children's learning, we hope to build a more complex understanding of young children's epistemology and practice through discussion.

Table 1: Shared Theoretical Lenses Across Session Papers

	Epistemology	Complex Systems	Inquiry	Practices
Wang	Personal Epistemologies		Classroom Life Cycle Inquiry	
Sacks & Levy		Physical + Social Complex Systems		Social Practice: Leaving for Recess
Keifert	Inquiry as a Way to Know the World		Families Engaging in Inquiry	Family Practices
Tu et al.	Role of Knowledge in Modeling	Bee-Flower Ecosystems	Play as Modeling	Embodied Play and Modeling

To focus our attention on building new understandings about working with this young population, each paper takes up two central questions: (1) How is existing LS theory drawn upon in each study? (2) How is new theory built or existing LS theory modified in each study? The goal of attending to these questions is that as a group of scholars, along with our discussant and other symposium attendees, might better understand the ways that existing theory does and does not work when studying young children. This conversation will support making new connections across different methodologies, settings, and content areas to better understand what shared understandings should inform the field.

Preliminary findings across papers indicate that many existing theoretical lenses within the Learning Sciences can be drawn upon to understand young children's sensemaking. At the same time, the papers show that drawing on existing theory may inform needed revisions to acknowledge the particular strengths of this population. For instance, while Wang found a strong match with prior uses of an existing framework in studies of young children's inquiry practice, both Sacks & Levy and Keifert found existing theory needed adjustments to account for the strengths of young children. In fact, both Sacks & Levy and Tu et al. demonstrate that children have particular resources that may be unique to this age (as compared to adults) and should thus inform potential learning designs, with Tu et al. articulating one such design. Collectively, these papers provide guidance on the nuances of drawing upon existing literature with this particular population that should inform both theory and future learning designs.

"Sometimes the Internet doesn't know everything": Exploring young children's epistemic reasoning in their inquiry practice

X. Christine Wang

This project investigated young children's (ages 5-6) epistemic reasoning during group scientific inquiry: What practical epistemologies (PEs) do young children demonstrate while engaging in their own inquiry practice? What are the roles of individual, peer and teacher actions in children's demonstrated PEs?

Developing epistemic beliefs (EBs)—understanding of the nature of knowledge and knowing (Hofer & Pintrich, 1997)—influences children's academic and social lives; for example, children who view knowledge as absolutely right or wrong have more difficulty understanding and synthesizing conflicting views, and taking others' perspectives (Kuhn & Weinstock, 2002; Pillow, 2002). Unfortunately, we know little about the origins of epistemological awareness or its early development (Bendixen, 2016; Hofer & Pintrich, 1997). Existing research often view EBs as explicit, coherent, and stable cognitive structures or utilizes questionnaires or hypothetical scenarios, which are unsuitable for young children (Metz, 2011). To overcome these theoretical and methodological challenges in studying young children's EBs, I adapt an existing LS theory, practical epistemologies (PEs) framework (Sandoval, 2005). PEs focus on beliefs that guide and justify students' epistemic decisions during science inquiry, either implicitly or explicitly. Methodologically, this framework advocates focusing on students' inquiry discourse and artifacts, and interviewing them to explore their reasoning behind epistemologically salient decisions.

This project was conducted in a kindergarten class where the teacher implemented a 12-week long scientific inquiry project (*Life Cycle)*. Scaffolded by the teacher, groups of 4-5 students investigated their own questions by following the inquiry cycle (Bruce & Davison, 1996; Katz & Chard, 2000). Data sources included videos, artifacts, and student interviews. Qualitatively we identified salient epistemic events during the inquiry sessions, and coded the interview along 6 categories: (1) general understanding of inquiry; (2) science content; (3) source of knowledge; (4) justification of knowledge; (5) certainty of knowledge; and (6) simplicity of knowledge. Quantitatively, we use statistical discourse analysis (Chiu & Khoo, 2005) to analyze connections among an individual's actions, his/her peers' actions, teachers' actions during science inquiry and children's PEs.

The qualitative analysis showed surprisingly sophisticated understanding among kindergartners about sources of knowledge and the needs to triangulate them in their own inquiry practice. For example, in a group discussion about "where did the FIRST frog come from?" when one child suggested "Google it," the other responded "Sometimes the Internet doesn't know everything!" Encouraged and scaffolded by the teacher, the group discussed utilizing multiple sources ("ask a scientist!" "check the book in the library") or ways to triangulate ("check if they say the same thing!"). It is evident children as young as 5-6 years old can demonstrate nuanced epistemic reasoning while engaging in their own inquiry practice. However, this was closely related to the teacher's willingness and encouragement for such discussion and his skillful scaffolding of the process. Similarly, peers also played important roles by actively participating, challenging, and pushing each other to articulate and defend their ideas,

This study shows the promising application of PEs framework to understanding young children's epistemic reasoning and inquiry practice. It operationalizes how to define/select salient epistemic episodes in a guided classroom inquiry project as well as broadens the unit of analysis beyond the individual level to include teacher guided and peer participated episodes. Therefore, it helps address the theoretical and methodological challenges in studying young children's EBs (Hofer & Pintrich, 1997; Metz, 1995). Practically, the study inform possible ways to facilitate development of scientific reasoning and improve motivation for scientific inquiry (Kuhn, 2000).

Development of reasoning about complexity among young children

Dania P. Sacks and Sharona T. Levy

The project explores how young children explain familiar complex systems, focusing on developmental (four-year olds and seven-year olds), and contextual (physical or social) aspects. Understanding complex systems is becoming a critical ability as many world problems involve understanding how system-wide phenomena result from local interactions (Bar-Yam, 1997; Wilensky & Resnick, 1999). The work takes a strong constructivist position that children have sense-making resources, which they can apply to complex phenomena. This is analogous to Papert's pioneering demonstration that children can recruit ordinary body knowledge to learn geometry (Papert, 1972, 1980), and diSessa's work on children's physical intuitions (diSessa, 1988). Building upon diSessa's theory, complexity p-prims are sought for. Sparse previous work has shown children's capacities to understand simple complex systems, such as robots (Levy & Mioduser, 2010), bee-hive simulations (Danish et al., 2011) and game-simulations (Peppler et al., 2013).

System Dimension	Physical System Examples	Social System Examples
Levels-Both Levels: Using both levels interchangeably	*That every marble was next to one another and they spun [around].*	*And all the children pushed at the door. Only three children managed to get out.*
Levels- Level Transition: Transition from one level to the other	*[The experimenter: So, what happened when it [the red marble] collided with another marble?] It collided with all the marbles.*	*Hmm everyone fell and then he ran, and he will run to the ya—to the yard.*
Emergence: Description of a process that generates the macro-level properties or behaviors from the micro-level actions and interactions	*Hmm if you (the experimenter) could do it faster (moving the box), so most likely a new color would be created.*	*No examples*
Interactions: The interactions between the agents within the system	*Hmm they {the marbles] kiss and then [they] separate.*	*All the rest stayed inside because they were pushing one another.*
Parallel Events: Events occur at the same time	*[The marbles] collide like this (no demonstration) together.*	*That the children are trying to get out and only three manage and all the others they are [squeezed together] and they cannot get out.*
Control: Whether an external force controls what happens in the system including influencing agent behavior, or the agents are autonomous in their behavior	*The marble wants to catch all the marbles*	*And then all the children ran to the door because they wanted to have a lot of recess time and then simply they tried to leave all at once…*
Predictability: Predictability of agents' actions	*Hmm if you (the experimenter) could do it faster (moving the box), so most likely a new color would be created.*	*They [children] are walking probably in the direction where children go.*
Non-Linearity: Small stochastic effects which make a big difference within the system	*Because they [the marbles] (A points to the small box) moved so quickly and they (A points to the big box) moved like this [demonstrates moving slow].*	*[the experimenter: Okay umm what would happen if the group was inside and this boy would push? (points to a button behind the other buttons)]* *Everyone [the children] would fall*
Equilibration: A process in which the system gradually stabilizes is described	*[The experimenter: What does the balls mixed mean?] That they like…the balls [the marbles] were here and they hmm spun [around] and hmm*	*And then this boy would push (the last child at the back) and then he would walk the entire line [of children] outside.*
Rates and Flows How agent movement and interaction affect the entire system. Agent speed is also a factor.	*They [the marbles] moved in every direction exactly and then they [the marbles] spread out.*	*[Children] were leaving and then the next three [children] and then the three aahh then [they] would just jump on them.*

Figure 1. Coding Guide for Analysis of Children's Interview Answers.

The study used videotaped clinical interviews, which included modeling and drawing, with 16 four-year olds and 17 seven-year olds individually during two sessions, 15-minutes each. To capture children's best reasoning, this study uses familiar scenarios: a rattle-marbles rolling in a box (physical) and children leaving class (social). Interviews were analyzed with a coding table (Figure 1) that included levels, emergence, interactions and equilibration as they play out in the two scenarios. 20 interviews were analyzed by two raters, with an inter-rater reliability of .80.

Complexity Ideas	Overall by domain Frequency (%)		Overall by age Frequency (%)		Social System Frequency (%)		Physical System Frequency (%)	
	Social System (N=33)	Physical System (N=33)	Four-Year Olds (n=16)	Seven-Year Olds (n=17)	Four-Year Olds (n=16)	Seven-Year Olds (n=17)	Four-Year Olds (n=16)	Seven-Year Olds (n=17)
Level- Relating	19 (58)	20 (61)	11 (69)	17 (100)	9 (56)	10 (59)	4 (25)	16 (94)
Level-Transitions	23 (70)	4 (12)	10 (63)	14 (82)	10 (63)	13(76)	0 (0)	4 (24)
Interactions	30 (91)	29 (88)	16 (100)	17 (100)	15 (94)	15 (88)	14 (88)	15 (88)
Emergence	0 (0)	1(3)	0 (0)	1 (6)	0 (0)	0 (0)	0(0)	1(6)
Control	7 (21)	1 (3)	4 (25)	4 (24)	3 (19)	4 (24)	1 (6)	0 (0)
Parallel-Events	17 (52)	4 (12)	9 (56)	10 (59)	9 (56)	8 (47)	1 (6)	3 (18)
Predictability	1 (3)	1 (3)	0 (0)	2 (12)	0 (0)	1 (6)	0 (0)	1 (6)
Non-Linearity	10 (30)	15 (46)	7 (44)	13 (76)	4 (25)	6 (35)	5 (31)	10 (59)
Equilibration	23(70)	30(91)	13 (81)	17 (100)	10(63)	13(76)	13(81)	17(100)
Rates & Flows	14 (42)	18 (55)	9 (56)	15 (88)	8 (50)	6 (35)	5 (31)	13 (76)

Figure 2. Children's Use of Complexity Ideas by Domain, Age, and their Interaction.

Interactions in a system, and equilibration processes were highly frequent (Figure 2); while, ideas related to predictability, emergence and control were used the least. Ideas relating to distinguishing between levels, parallelism, non-linearity, and rates-and-flows were used at a medium frequency. Seven-year-olds expressed more kinds of complexity ideas than four-year-olds for the physical system, but not for the social system. Four-year-olds used more ideas for the social system than the physical system. When looking at the frequencies, we can see that despite both scenarios being familiar, only the seven-year olds use higher rates of level-transitions and emergence in the physical system. For the social system, both groups similarly use most of the concepts.

A key finding is that young children use complexity ideas. This is surprising because in previous studies into adults' complexity thinking, difficulties were found unless they were experts in their respective fields (Jacobson, 2001; Hmelo-Silver et al., 2007). It is important to note younger children's greater use of interactions in making sense of the system, a quality, older students need to re-learn how to do. Moreover, attention to processes such as equilibration, usually not attended to by adults are evident. While we do not name the two as p-prims as they are not phenomenological, these two primal resources point to a distinct epistemology of what it takes to understand systems. It would seem that with development, we lose the local, interactive and dynamic percepts that guide our sense-making, and then need to re-learn them with more formal tools.

One important conclusion would be to strengthen these early abilities, so they are available as thinking tools throughout an individual's life. Learning environments can be designed to further foster such ideas and form a progression throughout school. The study also shows developmental aspects of complexity ideas, showing that while there are no age differences regarding social systems, older children can reason more complexly about physical systems. Based on this, one might consider designing learning environments for young children that harness their deeper understanding of social complex systems.

Family practices as cultural substrate in young children's engagement and adaptation of family practices

Danielle Keifert

Humans are cultural beings, developing within cultural communities that shape their understanding of how to engage with the world (Cole, 2007; Rogoff, 2003). MH Goodwin's (2007) *family culture* is a productive lens for understanding the epistemologies—understandings about what it means to know and learn—and practices—ways of engaging in learning together—that develop within families. The current paper draws upon and extends notions of culture (Rogoff, 2003) and family culture (Goodwin, 2007) in particular to understand the reciprocal influence of culture children's engagement in inquiry and children's influence on family culture. I claim (a) young children competently draw upon family culture in interactions, and (b) children play a role in shaping that family culture and related shared inquiry practices.

This paper is based on interaction analyses (Jordan & Henderson, 1995) of 80 hours of video data of everyday family activity for a subset focused on two children—Catherine and Charlie. The data presented here of both children (age 7) informs understanding the reciprocal influence of family culture on children's inquiry and children's interests on family culture through the analytical lens of substrate—"the sedimented outcome of earlier action, and the source of subsequent action" (Goodwin, 2018, p. 32).

Children competently engage in family practices. Patterns in interactions illustrate family practices as substrate for interactions (Keifert, under review). This is evidence as Charlie (7y 2m), his younger brother Michael (3y 7m), and Mom explored the story of Matilda while eating breakfast with Dad and newborn Katie (0y 1m). Michael and Mom first articulated a moral that it is not a good thing to go into other people's houses. Charlie drew upon their family inquiry practice and the interactional accomplishment of Michael and Mom's articulation of a moral to push back. Charlie suggested that it was OK in this case for Matilda to break into someone else's house because it was Matilda who did it (Figure 3). In the subsequent engagement in their family inquiry practice, Charlie and Mom explored who Matilda was in relation to Ms. Honey (her student) and who Ms. Honey was in relation to the women's house they broke into (her niece) as Charlie worked to justify Matilda going into the home. Charlie and Mom's interaction was representative of a pattern—a family inquiry practice of exploring narrative to understand character motivations and perspectives. This practice was part of the substrate Charlie and Mom drew upon to invoke the context of inquiry: making counter-claims supported by inquiring about characters, their actions, their relationships, and making interpretations about justified actions. Similar patterns were observed in Catherine's family.

Figure 3. Mom leans in towards Charlie as he challenges the stated moral.

Figure 4. Catherine offers Stuart a gluebooger.

Children also competently adapt family practices. Examining violations to practices helps illustrate their role as substrate. For instance, Catherine (7y 0m) engaged in her family practice of imagined self-projection—engaging in a thought experiment to explore the undesirable—when Catherine and Dad imagined eating "boogers" made from rolled up wood glue. But when Catherine actually offered Stuart a glue as a booger (Figure 4), Dad responded "That's kind of weird, Catherine." Despite Dad's admonishment, the inquiry practice served as a substrate for Catherine's adaptation of that practice for her own purposes, what she later called a "prank."

Charlie and Catherine competently engaged in inquiry by drawing upon family practices as known cultural substrate. Moreover, by age 7 Catherine and Charlie adapted family inquiry practices for their own purposes, thereby broadening their family repertoire to include new substrate for familiar inquiry practices. Doing so expanded the practices that were available for knowledge-building in their families. This evidence supports pushing past notions of family culture as part of a socialization process for children towards recognizing that as much as children come to be competent practitioners of valued practices (Rogoff, 2003), they are also active (re)interpreters of those same practices in pursuit of their own interests.

Understanding the role of culture in particular interactions, and positioning children as competent engagers in those interactions, allows us to understand how *children themselves shape family culture*. Understanding children's role in drawing upon and shaping culture in everyday interactions is a critical dimension of understanding the cultural nature of human learning and development, the ways in which family epistemologies and practice are both learned and shaped by children, and diversity of developmental paths within cultural communities (Rogoff, 2003).

Play and embodiment: Designing for early elementary students' strengths

Xintian Tu, Joshua Danish, Megan Humburg, Noel Enyedy, Danielle Keifert

Play has long been valued as an important practice in young children's daily lives; it is closely tied to cognitive and social-emotional development (Vygotsky, 1978). While play is often accepted in out of school settings, it has been rarely treated as a powerful learning tool in classrooms. Recent work on play showed the potential of having different types of play activity to support young children's science inquiry (Youngquist & Pataray-Ching, 2004, Enyedy et al, 2012). Our work on the Science through Technology Enhanced Play (STEP) project has focused on how young children (5-7 years old) might build on this practice of play to engage in scientific knowledge-building practices such as inquiry (Danish et al., 2015).

From social-cultural theory, the primary location for studying learning is in collective activity (Engestrom, 2008). Therefore, our focus is on how children's play activities can serve as the basis for modeling activities that are more recognizably scientific. The STEP environment was designed to use both play and embodiment as mediators of students' activity and learning. To support this, STEP uses a motion tracking system to track student's motion and drive a computer simulation (Danish et al., 2015; Danish et al., 2017). For example, students acting as bees see themselves as bees in the meadow on the projected screen (see Figure 5). In this paper, we're presenting STEP-Bees activities which involve students play-acting as bees as part of their inquiry into how bees collect nectar from flowers, thus unintentionally pollinating the flowers.

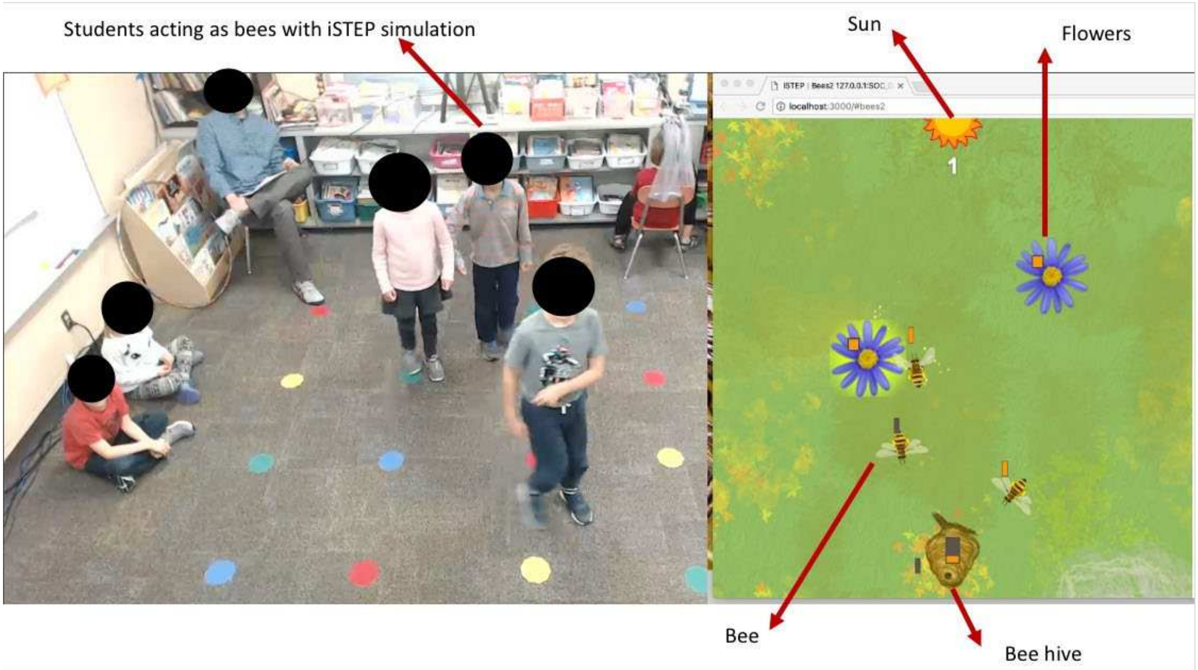

Figure 5. Students interacting with STEP (left) and the projected simulation (right).

We present data from one STEP: Bees implementation in one 1st grade, and one 2nd grade classroom at an elementary school in a small mid-western city. Forty-eight students participated in 8 sessions of STEP activities, and all classroom activities were videotaped for interaction analysis. Students' learning gains were assessed by a 13-item written multiple-choice test. Classroom interactions were analyzed to see when students' activity had features of play, modeling, or both. In addition, students participated in one-on-one interviews on their perception of play and scientific modeling (e.g. we asked students what it means to play as a bee or model the behavior of bees) so that we could better understand how students perceived these different practices and their relationship to the underlying rules of the honeybee system.

We found significant improvement from the pre-test score ($M = 6.08$, $SD = 2.99$) to post score ($M = 10.36$, $SD = 1.97$), $t = -9.237$, $p < .001$. The results from interviews indicate students recognized classroom play as a way for them to act and mimic bee behavior in a flexible and self-oriented way. In contrast, they recognized the importance of their knowledge of how bees are supposed to behave for shaping their scientific models to be scientifically accurate, suggesting epistemic awareness of the distinction between these activities. In the classroom interactions, students initially engaged in play as a way of having fun, and later oriented towards scientific rules to match real life. To characterize this range of activities we identified three forms of observable activity along a spectrum: 1) free play: when the rules of activities were flexible, students were able to develop their own object, and the rules of the science were not obvious in their play; 2) intermediate play with science rules: when students engaged with and explored the pre-set rules in STEP, they were also exploring the real rules of scientific phenomena; and 3) scientific narrative play: students' embodied movements were oriented by science rules while engaging in the play. This study builds on prior literature related to play and modeling to begin articulating how play can serve as a resource for engaging in scientific modeling activities, while indicating how students view these different activities.

References

Bar-Yam, Y. (1997). *Dynamics of complex systems*. Reading: Addison-Wesley, The Advanced Book Program.

Bendixen, L. D. (2016). Teaching for epistemic change in elementary classrooms. *Handbook of epistemic cognition*, 281-299.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77-101. doi:10.1191/1478088706qp063oa

Bruce, B.C., & Davidson, J. (1996). An inquiry model for literacy across the curriculum. *Journal of Curriculum Studies, 28,* 281–300.

Chiu, M. M., & Khoo, L. (2005). A new method for analyzing sequential processes: Dynamic multi-level analysis. *Small Group Research*, 36, 600-631.

Cole, M. (2007). Phylogeny and cultural history in ontogeny. *Journal of Physiology - Paris, 101*, 236-246.

Danish, J. A., Enyedy, N., Saleh, A., Humburg, M., DeLiema, D., Dahn, M., & Lee, C. (2017). *STEP-Bees: Coordinating embodied interaction with peers, teachers, and computer simulation to support learning*. Paper presented at the Annual conference of the American Educational Research Association, San Antonio, TX.

Danish, J. A., Enyedy, N., Saleh, A., Lee, C., & Andrade, A. (2015). *Science Through Technology Enhanced Play: Designing to Support Reflection Through Play and Embodiment.*Paper presented at the Exploring the Material Conditions of Learning: The Computer Supported Collaborative Learning (CSCL) Conference, Gothenburg, Sweden.

Danish, J. A., Peppler, K., Phelps, D., & Washington, D. (2011). Life in the hive: Supporting inquiry into complexity within the zone of proximal development. *Journalof Science Education and Technology, 20*(5), 454-467. DOI 10.1007/s10956-011-9313-4

diSessa, A. A. (1988). *Knowledge in pieces*. Cambridge: MIT Press

Enyedy, N., Danish, J. A., Delacruz, G., & Kumar, M. (2012). Learning physics through play in an augmented reality environment. *International journal of computer-supported collaborative learning*, *7*(3), 347-378.

Goodwin, C. (2018). Co-Operative Action. Cambridge University Press.

Goodwin, M.H. (2007). Occasioned knowledge exploration in family interaction. *Discourse Society, 18*(1), 93-110.

Hmelo-Silver, C. E., Marathe, S., & Liu, L. (2007). Fish swim, rocks sit, and lungs breathe: Expert-novice understanding of complex systems. *The Journal of the Learning Sciences*, *16*(3), 307-331. DOI: 10.1080/10508400701413401

Hofer, B. K., & Pintrich, P. R. (1997). The development of epistemological theories: Beliefs about knowledge and knowing and their relation to learning. *Review of Educational Research*, *67*(1), 88-140.

Jacobson, M. J. (2001). Problem solving, cognition, and complex systems: Differences between experts and novices. *Complexity*, *6*(3), 41–49.

Jordan, B., & Henderson, A. (1995). Interaction Analysis: Foundations and Practice. *Journal of the Learning Sciences, 4*(1), 39 - 103.

Katz, L. G., & Chard, S. C. (2000). *Engaging children's minds: The project approach*. Norwood, NJ: Ablex.

Koh, E., Cho, Y. H., Caleon, I. S., & Wei, Y. (2014). *Where are we now? Research trends in the learning sciences. Proceedings of the 11th International Conference of the Learning Sciences*. Boulder CO, 1, p. 535-542.

Kuhn, D. (2000). Theory of mind, metacognition, and reasoning: A life-span perspective. In P. Mitchell, & K. J. Riggs, (Eds.), *Children's reasoning and the mind* (pp. 301-326). Hove, England: Psychology Press.

Kuhn, D., & Weinstock, M. (2002). What is epistemological thinking and why does it matter? In B. K. Hofer, & P. R. Pintrich (Eds.), *Personal epistemology: The psychology of beliefs about knowledge and knowing* (pp. 121-144). Mahwah, NJ: Earlbaum.

Levy, S.T. & Mioduser, D. (2010). Approaching complexity through planful play: Kindergarten children's strategies in programming an autonomous robot. *International Journal of Computers in Mathematical Learning, 15*(1), 21-43.

McDermott, R. P. (1977). *Kids make sense: An ethnographic account of the interactional management of success and failure in one first-grade classroom*. Unpublished dissertation in the Department of Anthropology, Stanford University.
Metz, K. E. (1995). Reassessment of developmental constraints on children's science instruction. *Review of Educational Research*, *65*, 93-127.
Metz, K. E. (2011). Disentangling robust developmental constraints from the instructionally mutable: Young children's epistemic reasoning about a study of their own design. *The Journal of the Learning Sciences, 20*, 50-110.
Nasir, N. I. S., Rosebery, A. S., Warren, B., & Lee, C. D. (2006). Learning as a cultural process: Achieving equity through diversity. In K. Sawyer (Ed.), *The Cambridge Handbook of the Learning Sciences.* New York: Cambridge University Press.
Papert, S. (1972). Teaching children thinking. *Programmed Learning and Educational Technology*, *9*(5), 245-255.
Papert, S. (1980). *Mindstorms; Children, Computers and Powerful Ideas*. Cambridge: MIT Press
Peppler, K., Danish, J. A., & Phelps, D. (2013). Collaborative gaming: Teaching children about complex systems and collective behavior. *Simulation & Gaming, 44*(5) 683–705.
Pillow, B. H. (2002). Children's and adults' evaluation of certainty of deductive inferences, inductive inferences, and guesses. *Child Development*, *73*, 779-792.
Rogoff, B. (2003). *The cultural nature of human development*. New York: Oxford University Press.
Sandoval, W. A. (2005). Understanding students' practical epistemologies and their influence on learning through inquiry. *Science Education*, 634-656.
Vossoughi, S., & Gutiérrez, K. (2014). Studying movement, hybridity, and change: Toward a multi-sited sensibility for research on learning across contexts and borders. *National Society for the Study of Education*, *113*(2), 603-632.
Vygotsky, L. S. (1978). Mind in society: The development of higher psychological processes. Cambridge: Harvard University Press.
Wilensky, U., & Resnick, M. (1999). Thinking in levels: A dynamic systems perspective to making sense of the world. *Journal of Science Education and Technology, 8*(1), 3-19.
Youngquist, J., & Pataray-Ching, J. (2004). Revisiting "Play": Analyzing and Articulating Acts of Inquiry. *Early Childhood Education Journal, 31*, 171-178.

