MAKING SENSE OF SENSELESS THINGS: AN ENACTIVIST ANALYSIS OF HARMONY AND DISSONANCE IN PROBLEM SOLVING

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Operating from an enactivist theory of cognition, this work seeks to understand the emergent nature of mathematical activity mediated by manipulatives. Enactivism takes a biological approach and theorizes that perception consists in perceptually guided action enabled by cognitive structures that emerge from recurrent sensorimotor patterns (Proulx, 2013; Varela, Rosch, & Thompson, 1992). These processes are non-linear, unfolding, and ongoing events where meanings emerge and transform in interactions, not inside of minds and bodies (Malafouris, 2013; Proulx, 2019). Further, one's way of knowing is driven by an evolutionary imperative to act in an adequate, fitting, and harmonious way with one's environment (Maheux & Proulx, 2015). This search for harmony leads to a *structural coupling* between the individual and their environment with the individual's history of recursive interactions playing a crucial role in *structurally determining* this course of evolution (Proulx, 2013).

This work seeks to elucidate the nature of emergent mathematical activity mediated by manipulatives by addressing the question, *"What role might manipulatives play in the emergent processes of sense making?"* To do so, we analyzed the activity of "Dolly" and "Lyle" as they aimed to make sense of the flip-and-multiply algorithm for fraction division in a problem-solving interview using a manipulative Dolly created for engagement with fraction concepts. The data comes from a larger study that is exploring how an open-ended and iterative design experience centered in Making (Halverson & Sheridan, 2014) might inform prospective mathematics teachers' (PMTs') pedagogy. We took a revelatory case study approach to analyze and transcribe the video data (Yin, 2014), and focused our analysis on the particular interactions aiming to coordinate meanings of fraction division in the manipulative and in the algorithm that presumably substantiates those meanings (Malafouris, 2013).

Our analysis illuminates the role manipulatives can play in establishing a notion of sense making that is grounded in embodied understandings. For example, although Dolly and Lyle arrived at the correct answer with the manipulative early in their problem solving, they were dissatisfied because it did not seem to *fit* with the answer they derived from the algorithm. Eventually, this dissonance gave way as they established harmony between the two, thereby revealing the compelling power that embodied tool use can have for altering a space of possible actions and consequently on sense-making activity. Our analysis also reveals what might be problematic about a pedagogical practice where a procedure is adequate and *sense making* is not the criteria for fit. The enactment of the algorithm was disrupted through use of a tool, ultimately leading to an authentic understanding of what it means to *do* fraction division. These findings further substantiate extant arguments for engaging mathematics learners in embodied, tool-mediated problem-solving activity in conjunction with the learning of procedures.

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