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Discussion Group 9

How do Movements of Bodies and Artifacts Emerge in Mathematics Education?

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ABSTRACT The discussion group focused on embodied processes in mathematics teaching and learning. At this discussion group, we aimed to consider the origins of movements performed by students, teachers, and artifacts. We invited group participants to reflect on resources initiating bodily movement and on the agents who perform or share the movement from a theory of dynamic systems, a new-materialist perspective, phenomenological perspective, embodied cognitive science, and cultural-historical approach. We questioned when and how movements become recognized as mathematical activity and discourse; we also discussed the criteria in prompting students to act or suspend enactment and leave room for imagination and articulating prediction of the enactment.

Keywords: Embodiment; Gestures; Artifacts; Embodied collaboration; Theory of dynamic systems; New-materialism; Phenomenology; Embodied cognitive science; Cultural-historical approach.

1. Embodied Interaction: A Variety of Theoretical Perspectives

This discussion group was initiated by an international collective of researchers all concerned with embodied processes in mathematics teaching and learning. Operating from different perspectives that consider bodies as partaking in educational processes, we have been offering theoretical rethinkings of cognitive and affective processes in mathematical practices. Imagine a student who draws the graph of $y = x^2$ on grid paper. From a theory of dynamic systems that Abrahamson uses to argue for his embodied-design framework, this movement emerges as embodied adaptive coordinations in a complex dynamic system bearing agentive, environmental, and task constraints, such as figural features of the paper (Abrahamson and Sánchez — García, 2016). From a new-materialist perspective that Sinclar elaborates in the mathematics education field (de Freitas and Sinclair, 2014), an assemblage of the student with her capacities, the formula, and the paper with the virtual transformation that they imply is actualized towards the graph. From a phenomenological perspective, in which Nemirovsky was engaged for many years (Nemirovsky et al., 2013), objectification of

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a formula includes protention and retention of its usage, where the subject joins both the intentional horizon of the paper and the retentional formula usage, in fulfilling her intentionality of drawing a graph by moving the hand along the paper. From an embodied cognitive science perspective that is within Walkington's expertise, movement is driven by cognitive processing of the formula that is extended beyond the scalp in a distributed system of activity that includes both explicit use of embodied resources and implicit embodied associations (Walkington et al., 2019). From a cultural–historical account, represented by Shvarts in the team (Shvarts and Abrahamson, 2019), the student's drawing is mediated by cultural artifacts — the paper and the formula — and expresses an ideal (cultural) form of action, which the student appropriated in a previous collaboration with a more knowledgeable other.

2. Discussion Group Aims and Proceedings

At this discussion group, we aimed to consider the origins of movements performed by students, teachers, and artifacts. We invited the group participants to reflect on resources initiating bodily movement and on the agents who perform or share the movement. We worked on articulating the difference between motion per se and agential movement as well as when and how movements become recognized as mathematical activity and discourse (language, diagrams, gestures).

The session started with an introduction of corresponding theoretical perspectives by each of the organizational team members and continued with discussions in small groups that each applied a chosen perspective to the analysis of a shared one-minute video fragment. This fragment was filmed in November 2006 at an Aboriginal Headstart Daycare in Ontario, Canada. It presented a 4-year-old child, who, in a collaboration with a teacher–researcher, for the first time used a digital application, TouchCounts (Jackiw and Sinclair, 2014), to explore the operation of addition. After diving into the video fragment from different theoretical perspectives and revealing various aspects of embodied interactions between a child, a technological artifact, and a teacher, we discussed our insights jointly at the plenary discussion. Thirty-two researchers from Australia, Brazil, Canada, Chile, Finland, France, Germany, Israel, Italy, the Netherlands, Peru, South Africa, Sweden, UK, and USA joined the conversation.

3. Outcomes and Future Directions

Discussions brought forth the complexity of explicating the sources of the child's mathematical expressions. Different theoretical perspectives highlighted the role of the artifact's design and the teacher's and student's bodily dynamics in triggering and shaping embodied actions. Mathematical expressions coincided with bodily gestures and poses, being indispensable from materially articulated embodied ideas. Despite exploring various theoretical focuses, participants working in different small groups repeatedly noticed that bodily imitation of the adult's gesture apparently guided the student's performance. Mathematically relevant gestures seemed to occur without strict top-down cognitive regulation based on pre-given knowledge, but as a spontaneous emergent dynamical event enabled by material constraints. Those material constraints included cultural guidance by the teacher through gestures and physical forming of the interactional space. The teacher carefully steered the child to alternate between actively manipulating the digital artifacts and suspending the manipulating to predict the artifact's feedback.

Overall, the discussion highlighted a complementarity of various perspectives that evoked different aspects of embodied interaction in mathematics learning, yet revealing a unified phenomenon rather than providing contradictory visions. Further research questions may concern the emergence of a student's awareness of her mathematical expression and the role and form of pre-knowledge in shaping embodied expressions. When and how does a student come to know their own embodied ideas as mathematical? Another direction of future research might focus on the issue of engaging in physical manipulation versus suspending actual manipulation to form anticipation of the feedback from the (technological) environment. What is the potential of embodied theories in explaining mathematical thinking without direct physical enactment? A final direction concerns the political implications of new ways of sensing/making sense in mathematics, such as the visual and the haptic, and how they remain subordinate to the alphanumerical (language and symbols).

The work of this discussion group will be continued at annual and local conferences, such as the Congress of the European Society for Research in Mathematics Education (CERME) and the annual conference of the International Group for the Psychology of Mathematics Education (PME).

References

D. Abrahamson and R. Sánchez-García (2016). Learning is moving in new ways: The ecological dynamics of mathematics education. *Journal of the Learning Sciences,* 25(2), 203239.

E. de Freitas and N. Sinclair (2014). *Mathematics and the Body: Material Entanglements in the Classroom*. Cambridge University Press.

N. Jackiw and N. Sinclair (2014). *TouchCounts*. iPad application. Tangible Mathematics Project, Simon Fraser University.

R. Nemirovsky, M. L. Kelton, and B. Rhodehamel (2013). Playing Mathematical Instruments: Emerging Perceptuomotor Integration With an Interactive Mathematics Exhibit. *Journal for Research in Mathematics Education*, 44(2), 372–415.

A. Shvarts and D. Abrahamson (2019). Dual-eye-tracking Vygotsky: A microgenetic account of a teaching/learning collaboration in an embodied-interaction technological tutorial for mathematics. *Learning, Culture and Social Interaction*, 22, 100316.

C. Walkington, G. Chelule, D. Woods, and M. J. Nathan (2019). Collaborative gesture as a case of extended mathematical cognition. *Journal of Math. Behavior,* 55, 1–20.