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Embodied Learning and Artificial Intelligence: Expanding the bandwidth of learning technologies

H. Chad Lane and Olga C. Santos

Learning in Action

Marley is excited to learn about birds at the science museum. Because his language skills are still developing (and because he is five), his answers to questions are often accompanied by movement. For example, when asked what birds have, Marley instinctively flaps his arms while saying "wings" and touches his torso when answering "feathers". With a more difficult question, "Can you identify a Roseate spoonbill?" Marley struggles to remember the words but is able to express his understanding through movement: he extends his hand from his mouth outward to form a representation of a long beak, then dips his head forward and down, as if to go under water, while simultaneously scooping his hand to mimic catching a fish.

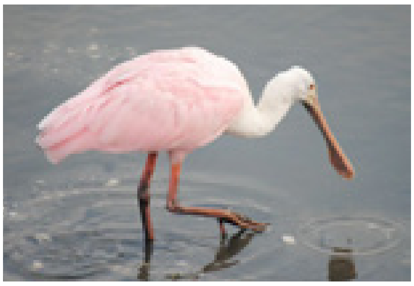

Photo: Jon Rouse

Why movement matters to learning

Although movements like Marley's may seem like child's play, emerging research in the learning sciences suggests that such movements actually provide a window into the development of his understanding. Marley's actions with his hands and body in this example not only align with and help complete his thoughts, they provide a powerful visual indicator that learning is taking place.

Embodied Learning captures the idea that movement, thinking and learning are interconnected. While generally understood that nonverbal signals play important roles in communication (e.g., nodding, expressing emotions), it is perhaps not as obvious that bodily movements can also reveal and even influence learning, much like we see with Marley's body-based representation of spoonbill physiology. Neuroscience provides a possible explanation as to why the mind and body work in this way: during human evolution, when abstract thought was being developed, it is believed that older areas of the brain that were originally dedicated to the motor system were repurposed.

What kind of movements matter?

The fact that specific kinds of movements can impact learning outcomes is one of the most important developments from research on embodied learning. Whereas characterizations of kinesthetic learning styles call for learners to simply be physically active while learning, embodied learning suggests educators should think about which movements are most appropriate for content being learned. It makes sense: when learners move in ways that are *congruent* with what is being learned, learning is accelerated. Gestures and full-body movement illustrate this important principle.

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Gestures are pervasive in communication, even to the point of being nearly impossible to suppress. For example, simple pointing gestures are used to ground conversations, such as to confirm that a learner and teacher are referring to the same thing. But they can also be used to express more complex thoughts. Metaphoric gestures perform this function by modelling and capturing representational aspects of a bigger idea, abstract concept, or idea that is difficult to describe with words alone. For example, in mathematics, the relative height of one hand from another or the drawing of lines in space can be used to form representations of ratios or slopes of lines, which in turn enhance understanding.

Graphic adapted from Martha W. Alibali & Mitchell J. Nathan (2011): Embodiment in Mathematics Teaching and Learning: Evidence From Learners' and Teachers' Gestures, Journal of the Learning Sciences, DOI:10.1080/10508406.2011.611446 with permission from Taylor & Francis.

Moving beyond hand and head gestures, full-body movements have also been linked to improved learning outcomes. The full-body experience of the senses, and moving through space, facilitates the understanding of abstract concepts. For instance, the practice of Aikido (a defensive martial art that consists of movements that redirect the momentum of an opponent's attack, so that the attacker is either thrown to the floor or immobilized), can help students to "feel" the angular motion and improve their learning of some Laws of Physics.

Expanding the “bandwidth” of learning technologies using movement and AI

The basic idea that movements matter for learning suggests that learning technologies could be dramatically improved by expanding their “bandwidth”; that is, by including physical motion as one of the input types a system takes into account.

Expanding a learning system’s capability to consider learner’s movement seems like the natural next step in the evolution of education technologies. To deliver personalised experiences, AI-based educational technologies typically require a learner model (which is a system’s evolving estimate of what a learner believes, thinks, and is trying to achieve). The avalanche of rich, varied and continuous streams of meaningful data made available through sensing technologies (e.g., smart watches and other sensors) and which can be processed in real time with Big Data techniques means that intelligent technologies will be able to evolve in order to develop a more integrated and coordinated estimate of how a learner changes over the course of a movement-enhanced educational experience - that is, it will be able to create better learner models through increased “bandwidth”.

This exciting work is well-suited to an AI-focused approach for two principle reasons. Firstly, interpreting physical movements (e.g., gestures, facial expressions, physical representations) is a challenge best met by robust and flexible approaches that are commonplace in AI (including computer vision and activity recognition). Secondly, a system’s internal estimate of a learner’s current state can involve a number of established AI subfields, including knowledge representation, uncertain reasoning, and machine learning.

Prospects for making this real

The fact that movement and thought can both reflect and influence one another is a powerful idea. It has implications about how we approach teaching and learning and how we build the next generation of educational technologies. In order to do this, research will need to move forward on several fronts:

1. Researchers will need to capture *ideal* and *developmental models* of how learners move, to what degree individual differences matter, and how movement-related assessments influence estimates of learning.
2. Wearable technologies and sensors need to continue progressing to facilitate data collection in a non-intrusive way, extend the information that can be gathered, and improve the accuracy of their measures. Electronic textiles (or e-textiles) provide an interesting potential route to reduce the intrusion level while gathering data.
3. More user studies will be needed to design and build the next generation of learner models that incorporate movement and model links to cognition. This approach for user modelling would consider traditional inputs from learning environments (e.g., keyboard, mouse and touchscreen interactions, words spoken, tracked problem solving steps) as well as information about the learner’s body collected with wearables and e-textiles.
4. Further research will be needed to define the *personalisation* logic required for embodied learning and to further elaborate the critical role movement plays in learning. It is likely that this kind of knowledge is tacit - that it exists in the minds of educators, acquired after years of teaching. Thus, in order to make this knowledge explicit and structured, educators need to be involved in the elicitation of what kinds of embodied personalisation and support may be required for students.

H. Chad Lane is Associate Professor of Educational Psychology & Informatics at the University of Illinois, Urbana-Champaign, and is a lead researcher on the Move2Learn project. His work is supported in part by the National Science Foundation under grant number DRL-1451290.

Olga C. Santos is the R&D Technical Manager at aDeNu Research Group in the Artificial Intelligence Department of the Computer Science School at the Universidad Nacional de Educación a Distancia (UNED) in Madrid (Spain). She developed the TORMES methodology, which elicits personalisation opportunities from educational practice.

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