1 Embodied Cognition and Its Educational Significance

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Historically, the human mind was considered the sole source of knowing, thinking, and teaching, with the body considered both separate and inferior. Psychologically, cognition was seen as disembodiment (*res cogitans sine corpore*), in which the perceptual and motor systems were not considered relevant to understanding "central" cognitive processes (Wilson, 2002; Woodward et al., 2009). As such, classical views of cognition from psychology emphasized the storage and use of knowledge based upon mental representations (symbols), devoid of how the initial information was perceived through the body and the sensorimotor systems (Fodor, 1975, 1983; Newell & Simon, 1972; Pylyshyn, 2009; Tulving, 1983; for recent reviews, see Fugate et al., 2018; Macrine & Fugate, 2020), and separated from the brain's modal systems for sensing, action, and affect (Smith & Medin, 1981). Philosophically, the body was seen as an impediment to the mind's expansion and capabilities—an albatross levying a heavy drag on self-realization (Bordo, 1993; Macrine, 2002). This classical approach denied emotional and bodily reality altogether (Robinson & Pallasmaa, 2015), but the latest neuroscience evidence validates an embodied view of mind and its connection to the body.

Classical Views of Cognition

Since the time of Aristotle (384–322 B.C.), the body and mind were seen as separate and hierarchical in nature. Specifically, Aristotle believed that the mind ruled over the body, and reason over the emotions (Barnes, 1995). As a result, one had to discipline and dominate the body and emotions in order to free the rational mind. These assumptions informed René Descartes's (1596–1650) notions of the dichotomous nature of the mind/body separation (Ryle, 1949). He contended that the mind must be cleared, and the foundation of knowledge laid (preconceived universal truths), an idea known as foundationalism. Metaphorically, the

idea was like an architect demolishing and clearing the land before building a house. In his "First Meditation," Descartes posited that trusting perception alone (i.e., the senses to explain experience) was limiting because the senses can be deceived (Descartes, 1637/1998). For example, Descartes argued that far-away objects appeared to be quite small even though they were not actually so, and therefore our bodily senses were not reliable. Descartes insisted that the mind must be absent of any biological or social influences that might contaminate or taint true knowledge or reason. Cartesian theory held that the mind determined physical acts, and therefore volitional acts of the body must be caused by volitional acts of the mind.

Gilbert Ryle (1900–1976), the British philosopher, challenged Cartesian dualism when he suggested that sensations, thoughts, and feelings do not belong to a mental world distinct from the physical world. In fact, he called this the myth "the ghost in the machine" (Ryle, 1949). Building on this, Ryle theorized that the body and mind do cooperate, but only accidentally, with each retaining full autonomy from one another. In other words, all mental and physical activity occurs simultaneously but still separately.

Although a greatly scaled-down history, the legacy of Descartes's dualistic theory of knowledge continues to shape modern views of knowing and learning. Foundationalism, the basis for Western epistemology, philosophy, and the sciences, still dominates educational thought. So how do we move beyond classical views of cognition to embodied cognition and an embodied approach to teaching and learning?

Education as a Result of the Classical View of Cognition

Historically, Western philosophy conceptualized the body as an instrument to be directed and a possible source of disruption to be controlled by our rational faculties (Lennon, 2019). These types of grand narratives have attempted to explain our social reality in its entirety. As a result, the mind and body separation informed the foundation of Western thinking about how knowledge is acquired and how learning occurs. In the case of psychological and educational theories, these narratives have ranged from behaviorism and stimulus-response thinking to blank slate processing, information processing, computational processing, and recently to artificial intelligence (more on this later). None of these views saw the body (or senses) as instrumental to cognition. In addition, these approaches paid little attention to the roles of learning in the affective domain. Both the teachers' and the students' bodies, as well as the social contexts in which learning occurs, were seen as irrelevant to the teaching-learning event (Macrine, 2002).

Constructivism emerged as an alternative, and it rescued the learner from the behaviorists' role of receiver of knowledge. However, constructivism still posited that knowledge was a product of the "individual's mind" and fashioned its mental schemas to correspond with reality or social influences. Emphasizing cognition through critical thinking left the focus of learning as purely an intellectual activity (Brookfield, 1985; see Ollis, 2012, for a review). Here, knowledge was still seen as individual in nature and based on the technical interests of the rational individual seeking control over life and the environment (Lave & Wenger, 1991). The implication for learning was that it is basically a private, individualistic matter.

The resultant constructivist pedagogical approaches took students out of the complex and dynamic life of everyday activities to sit them down in front of workbooks, skills, and drills (Newman et al., 1989). This model neglected the situated body and continued to rely on a noncontextualized, disembodied curriculum that inevitably resembled its predecessors. In fact, Matthews (1992) critiqued constructivism as the well-known metaphor "a wolf in sheep's clothing"—or to change metaphors, like the empiricists' wine served up in new wineskins. Ernst von Glasersfeld (1987, 1995), the father of radical constructivism, wrote that it is difficult to make the case for constructivism because its arguments almost always get tangled up within the old epistemological web from which constructivism desperately tried to free itself.

While psychology has been more open to progressive notions such as constructivism, social constructivism, and radical constructivism, many of these models still bare the same computational cognitive orientations. Schools, whether they are conscious of it or not, still work hard to separate the mind from the body (Macrine, 2002): Cartesian dualism is still pervasive throughout school settings. The teacher is seen as a "talking head"—a disembodied and disempowered conduit for core curriculum. These disembodied threats come in the form of rote memorization, mindless drills, and skills in preparation for standardized testing. Even now, the ramifications of our epistemological heritage continue to have quite an effect on how we conceptualize knowing, learning, and teaching.

Philosophical and Psychological Influences on Embodied Cognition

In contrast to the classical views of cognition, the famous philosopher Maurice Merleau-Ponty understood the importance of not just knowing why but *how* we gain knowledge (1962; see also O'Neill, 1974). Merleau-Ponty's (1962) notion of knowledge emphasized *I am my body*. Against Cartesian dualism,

Merleau-Ponty's existential phenomenology maintained that thinking was a fully embodied event: people perceive the world first and foremost through their bodies. He argued that cognition cannot be understood without the body's engagement with the world (see also Leitan & Murray, 2014; Marshall, 2008; Merleau-Ponty & Fisher, 1965). Lather (1991) insisted that we foreground the relation between the knower and known, teacher and taught, from an embodied perspective.

In the field of psychology, John Dewey (from works between 1925–1953), echoing William James (1892), suggested that higher-order cognitive functions are adaptations generated by interactions with the world. Both James and Dewey rejected the "rational psychology" drawn from Cartesian dualism. Later, James Gibson's "ecological theory" (1979) married both phenomenological (i.e., the *subjective experience*) and naturalistic perspectives. Gibson argued that perception was direct and the environment meaningful (see Leitan & Chaffey, 2014, for a review). Consequently, Gibson suggested that there was no mind between perception and action, and that action was based in the body, supported through evolution and the environment. Gibson called these "affordances," the idea that opportunities for action are provided by a particular object or environment.

Most recently is the added idea that the brain's role is to predict incoming stimuli to exert action. Continuing these ideas, developments in robotics (see Brooks, 1991) and dynamic system theory (see Beer, 1998; Thelan & Smith, 1994) treat cognition as arising from interactions with the world. In one of the most widespread notions of the mind, Andy Clark (2013) has posited a bidirectional, iterative relationship between sensorimotor input and conceptual knowledge, such that the brain is constantly predicting what sensory and bodily information is being encountered and then using stored knowledge via feedback to refine these predictions (for a similar view, see Barrett, 2017, discussed in detail in Fugate & Wilson-Mendenhall, chapter 18 in this volume). In fact, some robotics researchers have argued that true artificial intelligence can only be achieved when robots are able to connect sensory and motor skills through a body (see Brooks, 1991; Pfeifer, 2001, 2006).

Theories of Embodied Cognition

Our current understanding of human thinking and cognition rejects Cartesian dualism in favor of embodied cognition, which grounds cognition in sensory and motor activity. As a result, cognitive psychology has undergone a theoretical shift to acknowledge that sensorimotor processing is fundamental to understanding information (Smith & Sheya, 2010).

Embodied cognition suggests that the physical body plays a significant causal role, or a physically constitutive role, in cognitive processing (see Wilson & Foglia, 2015). Some of the core principles of embodied cognition are derived from the early ideas of developmental and educational psychologists (e.g., Dewey, 1938, 1989; Kolb, 1984; Piaget, 1952, 1968; Montessori, 1969; Rogoff, 1990; Vygotsky, 1978). Early work on action-on-thinking can also be seen in sociocultural psychology (e.g., Vygotsky, 1978), activity theory (e.g., Gal'perin, 1992; Leontiev, 1978), and apprenticeship in thinking (e.g., Rogoff, 1990) and by a variety of perspectives of learning, activity, and knowledge appropriation (e.g., Brown et al., 1989; Lave & Wenger, 1991; Robbins & Aydede, 2009; Rogoff, 1990; Wilson & Foglia, 2015).

Hockey and Allen-Collinson (2009) wrote that phenomenologically "we know the world through the body, just as that body produces the world for us" (p. 117). From this perspective, experiences are always embodied and relational, and the body plays a central role in shaping our experience of the world (van Amsterdam et al., 2017). Therefore, thinking extends throughout the body and is scaffolded upon a material and social world (for corresponding views, see Bahler, 2016; Clark, 1998; Damasio, 1994; Gallagher, 2005; Gopnik, 2009; Rowlands, 2010; Sheets-Johnstone, 2011; Shapiro, 2014; Yancy et al., 2014).

Barsalou's (1999) perceptual symbols systems (PSS) was one of the first explicit, psychological theories of embodied cognition. Specifically, Barsalou stated that knowledge is reenacted (i.e., simulated) through the perceptual and sensory systems it engages (e.g., auditory, visual, motor, and somatosensory). According to PSS theory, thinking about an action evokes the same visual stimuli, motor movement, and tactile sensations that occur during the act itself (Barsalou, 2003, 2008). The experience is captured by the sensory and perceptual systems and can be later used to re-create (through simulation) the experience without the actual stimulus (i.e., when just thinking about the knowledge).

Although there are a number of theories of embodied cognition, they are all united in their emphasis on the body functioning as a "constituent of the mind," rather than secondary to it (see Leitan & Chaffey, 2014, p. 3; Shapiro, 2007). Two common themes emerge across such embodied theories. First, the body and the world (environment) are integral to form, integrate, and retrieve knowledge, and knowledge is *grounded* or *situated* in the interactions between the individual and the environment. In some versions, *grounding* represents how mental representations are understood and learned (e.g., Barsalou, 2008; Glenberg & Gallese, 2012; Lakoff & Johnson, 1999). In some cases, language is thought to be the tool that binds together individual, heterogenous instances underlying abstract concepts because direct simulation would be harder than for concrete concepts (Borghi & Binkofski, 2014; Mazzuca et al., 2017; also

see Fugate & Wilson-Mendenhall, chapter 18 in this volume). In other cases, metaphors are thought to ground abstract concepts (Lakoff & Johnson, 1980). In other versions, there is no grounding necessary because there are no mental representations; rather, the individual's interaction with the environment *is* the unit of knowledge (e.g., Hutto, 2005). Second, knowledge is *simulated* (Barsalou, 1999, 2008; Gallese, 2009), such that thinking and recalling information is re-experiencing the bodily states at the time of encoding and does not represent amodal (symbolic) concepts. Although the contents of simulation are in the past, simulations occur in the present and can therefore be affected by current constraints as well.

Recently, embodied cognition has extended its reach into "4E cognition," in which cognition is not only *e*mbodied, but *e*mbedded, *e*xtended, and *e*nacted (see Gallagher as cited in Rowlands, 2010). Specifically, *embedded* refers to the fact that our bodies are situated in the environment, and our bodily capacities are geared toward current concerns and goals (i.e., affordances; see also Pouw et al., 2014). *Extended* refers to the fact that the boundaries of mind are engaged in enculturated practices, routines, societal norms, and the like. Finally, *enacted* refers to the fact that the body is self-producing and adaptive, with its own identity as it draws from the physical environment on which it depends. The body is a continually changing structure that determines its own actions on itself and its world. These assumptions bear resemblance to embedded cognition (Pouw et al., 2014), which suggests that perceptual and interactive richness "embed" a person's cognitive activity in the environment.

Today, researchers in various research areas such as developmental psychology (Thelen & Smith, 1994), biology (Maturana & Varela, 1987), language (Lakoff & Johnson, 1980), neuroscience (Chiel & Beer, 1997; Kiefer & Trumpp, 2012; Rizzolatti & Arbib, 1998), and philosophy (Clark, 1998, 1999; Varela et al., 1991) are rethinking and incorporating the role of the body in their disciplines. For instance, studies using functional magnetic resonance imaging show that motor portions of the brain re-create physical experiences when we read, see, or hear of them (Bergen, 2012). While it is understood that movement and action help to shape our perception and learning in early life, they also continue to impact the way we experience the world throughout development and into adulthood (Kontra et al., 2012).

Embodied Learning: Shifting Educational Models

As a result, embodied cognition holds promise for understanding the role of action and experience in learning contexts, as well as using action to scaffold

learning in more formal educational settings later in development (Kontra et al., 2012). Derived from these principles, embodied learning constitutes a contemporary pedagogical theory of learning that emphasizes the use of the body in educational practice as well as student-teacher interaction both in and outside the classroom (Kosmas & Zaphiris, 2018; Smyrnaiou et al., 2016). Embodied learning posits that an action-to-abstraction transition includes a variety of body-based techniques (i.e., gestures, imitations, simulations, sketching, and analogical mapping) (Weisberg & Newcombe, 2017). For example, the mirror neuron system contains neurons that not only fire when we undertake an action but also when we observe others undertaking the same actions (Rizzolatti & Craighero, 2004; see Butera & Aziz-Zadeh, chapter 16 in this volume). This system appears to play a fundamental role in both action understanding and imitation; therefore, higher cognitive abilities might be dependent on the reenactment of sensory and motor representations (see also Caramazza et. al., 2014).

Alibali and Nathan (2018) have developed several principles that highlight the importance of actions as they relate to embodied learning. (1) Action matters for cognitive performance and learning. (2) Observing others' actions can activate action-based knowledge. (3) Imagining (or mentally simulating) actions can activate action-based knowledge. (4) Simulated actions are sometimes manifested in gestures and forms of representational action. They concluded that these principles, which focus on action, also have widespread implications for the Learning Sciences, including instructional design and assessment. This idea also includes the use of "manipulatives" (physical objects that can be touched and moved with the hands during problem solving and learning) (see Donovan & Alibali, chapter 10 in this volume). This also means that, as technology and digital content become more integral to learning in the classroom, designers and scientists should consider such principles when incorporating mediated content (see Trninic & Abrahamson, 2013; see Johnson-Glenberg, chapter 15 in this volume).

In terms of teaching students with learning differences, there are a number of notable adaptive embodied interventions that are available (see Tancredi et al., this volume) and also therapies for children with disabilities/delays/disorders, including autism spectrum disorder (Ollendick & King, 2000; Srinivasan & Bhat, 2013; see Davis et al., chapter 17 in this volume). Embodied approaches have also been developed to treat adults with mental illness and improve emotional well-being, and they include body-based therapies (Genosko, 2002; Michalak et al., 2012) as well as attention and disambiguation of affective states through mindfulness and increased emotional granularity (see Fugate & Wilson-Mendenhall, chapter 18 in this volume).

Because learners' bodies represent their past and present experiences and constitute educational discourses (Hunter, 2004), individuals bring their own *lived* bodies into the classroom (Hooks, 2003). Embodied learning recognizes that understanding and retention are affected by the body and sensory input. Individuals' interactions with the world impact their own motor and perceptual systems and thus will be also shaped by their culture (see Leung et al., 2011). Said another way, the cognitive structure of an individual—as defined by his or her own experiences and those supported by cultural norms and language—informs how information is first experienced as well as later simulated (Fugate et al., 2018). Specifically, Fugate et al. (2018) have suggested that this implies two things. (1) Similar actions may be encoded differently within the brains of different individuals because their perceptual and motor systems have had a different set of experiences that inform their current experiences. (2) The representation of this information may be different for individuals from different cultures, which have different priorities, rules, words, and linguistic metaphors to explain the world around them. Thus, the implication for embodied learning and teaching is that the learner needs to be seen and taught as a whole being, permitting learners to experience themselves as an integrated whole, rather than with separate mental and physical mechanisms isolated from each other (see also Stolz, 2015).

Conclusions

The link between neuroscience and education can create viable embodied applications for education. Clearly, embodied cognition and embodied learning show promise and provide a starting point to advance our understanding of how perceptual, sensorimotor, and multisensory approaches can facilitate and encourage learning. In sum, embodied cognition scientifically endorses and advances sensorimotor learning and offers potentially useful tools for educators' understanding of teaching and learning (Macrine & Fugate, 2020). Conversely, if educators remain unaware of the potential influence that embodied cognition/learning can make on educational practice, then suboptimal teaching and learning methods will prevail. As a result, we believe it is important for neuroscience and education to form effective partnerships, and that researchers, educational psychologists, teachers, and program designers consider how they can promote the principles of embodied learning in the classroom, curriculum, technology, and beyond.

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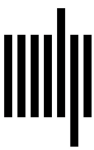

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