Embodied Thinking as a Trans-disciplinary Habit of Mind

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"First of all," he said, "If you can learn a simple trick, Scout, you'll get along a lot better with all kinds of folks. You never really understand a person until you consider things from his point of view-"
"Sir?"
"-until you climb into his skin and walk around in it."
–*To Kill a Mockingbird*
(Lee, 1960)

Picard: "It's a boyhood fantasy, Data. I must have seen this ship hundreds of times in the Smithsonian, but I was never able to touch it."

Data: "Sir, does tactile contact alter your perception of the Phoenix?"

Picard: "Oh, yes. For humans, touch can connect you to an object in a very personal way. It makes it seem more real."

Data: "I am detecting imperfections in the titanium casing. Temperature variations in the fuel manifold. It's no more real to me now than it was a moment ago."

Troi: "Would you three like to be alone?"
– *Star Trek: First Contact*
(Berman, 1996)

In her book *A Feeling for the Organism* (1983), Evelyn Fox Keller describes the life story of Barbara McClintock, American cytogeneticist and Nobel Laureate, who worked for decades to unravel the mysteries of genetics. McClintock's career began at the same time as the rise of genetics as a science, and her extensive research on breeding corn in the 1920's and 30's established her as a top-notch scholar in cytogenetics. But the discovery of DNA and the ensuing focus on molecular biology meant that her methods of inquiry and research, which were often naturalistic and based on observation of the effects of gene expression, lost their sheen. Undaunted she persevered and continued her focus on the genetics of corn, observing not only microscopic aspects of her subject, but also becoming acutely aware of how her plants developed and reacted to their environment. This difference in methods and approaches left her colleagues unsure of how to interpret her work, often questioning or dismissing its legitimacy, thus leaving her to work in near isolation for two decades. There is no doubt that sexism played a role in her treatments by other geneticists, yet there was also something else at play here. McClintock's method of inquiry went beyond a simple mismatch of the fields' methods. She came to see her methods as an experience that allowed her to feel and think more deeply about her subjects.

McClintock described part of the process as "*a feeling for the organism*" (pg. 198), by which insights came to her through patience and careful observation, which allowed her to empathize and develop a *physical feeling* for her plants (even at a level invisible to the naked eye). As McClintock described it:

> I found that the more I worked with them [chromosomes] the bigger and bigger [they] got, and when I was really working with them I wasn't outside, I was down there. I was part of the system. I was right down there with them… I even was able to see the internal parts of the chromosomes -- actually everything was there. It surprised me because I actually felt as if I were right down there and these were my friends.

McClintock's tendency to "make friends" with her plants and physically imagine their processes also gave her the feeling she had become a gene or chromosome herself. As such, she could better understand the processes that occurred in the cell nucleus

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and then connect it to the manner in which specific breeds of corn grew. She immersed herself in developing this empathetic "feeling" for her subjects, saying:

> "You need to know those plants well enough so that if anything changes, … you [can] look at the plant and right away you know what this damage you see is from – something that scraped across it or something that bit it or something that the wind did." (pg. 198).

It was this approach that let her to discover something that went against the existing dogma of molecular genetics—the fact that genes could actually "jump" around within the chromosome. By the 1960's and 1970's, McClintock's work could no longer be ignored and led ultimately to her Nobel Prize for her discovery of genetic transposition, the appropriately called "jumping genes" hypothesis.

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Our interest in McClintock's story comes not from seeking to better understand genetics but rather what it tells about how scientific breakthrough often happens. So the point is not just that McClintock was vindicated, but rather that her embodied methods were shown to be valid and productive. This feeling of empathy and/or the physical sense of her inanimate, microscopic subjects of inquiry that McClintock described is a prime example of the trans-disciplinary skill of embodied thinking.

In Mishra, Koehler and Henriksen (2011), we describe embodied thinking as one of the seven trans-disciplinary skills. As the example from McClintock above indicates embodied thinking, in our conceptualization, includes two related (yet distinct) skills: *kinesthetic (or body) thinking and empathizing*. These skills blend the physical, the mental, and the emotional aspects of how we think and experience the world. Kinesthetic thinking is thinking with the body, or the physical sensations of feeling, movement, muscles, posture, touch, balance, and so on, as connected to the mind and thought processes. Empathizing involves putting oneself into the shoes of another, to feel what they feel and experience the world through their eyes. It is described as being able to "put oneself in the shoes of another" (or their "skin" as the quote from *To kill a mockingbird* exemplifies in one of the quotes that starts this article). These two are connected in that both involve the cognitive processes that locate the self in either of two ways — in the first way in one's own body or physical presence, and in the second within "another", which interestingly enough can be another individual or even an inanimate object (such as in the McClintock example). In this article, we examine embodied thinking through examples of how it works in the world and consider how it lets us experience and feel knowledge as we learn and create.

Putting the Body Back into the Mind

The field of education often extols the virtues of abstract thought, free from the constraints of the physical world. While the ability for abstraction is a valuable skill, there remains a core part of human cognition that is rooted in the physical body – and to minimize its value is to completely misunderstand the nature of thought and knowledge.

Johnson (1987) notes that much classic epistemology has centered on knowledge and thinking as a pure and abstract concept. Objectivist positions have dominated the scholarship of meaning and rationality, and these positions tend to view thinking as intangible – divorced from our physical selves and world. According to Johnson (1987), the role of the body was ignored through much of the history of education, psychology and philosophy, because it was thought to introduce subjective elements that were irrelevant to the nature of knowledge, and because thoughts were deemed to be incorporeal and abstract. From ancient Greek philosophers to modern cognitivist theories of learning, the function of mind-body connection was largely disregarded.

In recent decades however, scholars of embodied cognition have begun to point to increasing evidence of the ways that the body and mind work together to contribute to our perceptions of the world, our learning experiences, and the very foundations of much of human knowledge. Johnson (1987) refers to this move towards embodied cognition as "putting the body back inside the mind". He writes that:

The embodiment of human meaning and understanding manifests itself over and over, in ways intimately connected to forms of imaginative structuring of experience…(This) does not involve romantic flights of fancy unfettered by, and transcending, our bodies; rather, they are forms of imagination that grow out of bodily experience, as it contributes to our understanding and guides our reasoning. (pg. xiv).

Núñez et al. (1999) describe how this plays out even in the field of mathematics (a knowledge realm often considered highly abstract). Yet in this seemingly abstract realm even basic ideas show a kind of "stability" over the course of history. Such consistency of human ideas over time suggests that multiple aspects of bodily thinking are at work in knowledge construction. It reveals a common set of neural/bodily structures that help people to construct concepts consistently. But it also requires that our mathematical constructions be drawn from out of our everyday physical experiences in the world, such as spatial relations, motion, object manipulation, space, and time.

Mathematics then has its basis in the senses of our body. For example, the physically felt conception of the idea of "balance" in our bodies is related to how we understand the idea of "balancing" equations. It relates to our concept of how we establish equilibrium. Without feeling the ability to balance our bodies and deriving some conceptualization of space and how we move through it via experience, the field of mathematics would have no solid context from which to build our conceptions.

In this, the embodied perspective reveals how mathematics is a discipline built on tangible and concrete human experiences and common ideas developed in our physical bodies over thousands of years of consistent experiences. Embodied cognition suggests that not only mathematical concepts, but all of our conceptual scaffolding, is grounded in body thinking and experiences (Núñez et al., 1999).

Consider for instance the example of Maryam Mirzakhani, recent recipient of the Fields Medal, who has described herself as an avid doodler when she is considering a mathematical problem. She describes how the act of drawing allows her to focus, bringing together pieces of a problem that are not yet clear, and that "the process of drawing something helps you somehow to stay connected" (Klarreich, 2014). In fact, this tactile sense of "connection", and development of understanding through physical action resembles the idea expressed in the Star Trek quote at the beginning of this piece. But for Mirzakhani it goes even beyond the simple act of doodling, into the more complex domain of math and body thinking. She is currently considering how the abstract shapes and surfaces of her research topic (hyperbolic surfaces) interact within their theoretical space. This physical activity and imagined physical space are both aspects of embodied thinking.

The concept extends to multiple disciplines and contexts. Engineers report that they can feel the tension in points of a bridge they are constructing. Children become excited about dinosaurs if they can climb upon a sculpture of one to gain a point of view, touch the 'skin', and physically feel the experience of being a dinosaur – pretending to roam and hunt like a Tyrannosaur. Students often claim that they think clearly when they are moving, which is not without physiological merit (Oppezzo & Schwartz, 2014). Embodied thinking is the idea that these physical actions are as much a part of the thinking process as the work occurring between the ears.

A Tool for Thinking Across the Disciplines

The two components of kinesthetic thinking and empathetic thinking can each play a role (individually or together) in how this skill operates. Kinesthetic thinking is described as "thinking with the body, including sensation of muscle, skin and sinew; and the feelings in the body of movement, balance, and tensions" (p. 11). This goes beyond perception of our bodies' current sensations and includes the use of movement and physical senses to aid in reasoning and construction of new knowledge. This type of "proprioceptive thinking" also includes how we feel in tactile and emotional ways. While movement often makes up the better part of kinesthetic thinking, other proprioceptive and visceral sensations are also a part of it (Root-Bernstein & Root-Bernstein, 1999). Given the span of this "felt knowledge", it is not hard to see how this realm of thinking can extend to many disciplines.

In the field of art, abstract painters often think in tactile bodily ways, using their memory and muscles in communication with their paints and brushes, to express how they identify with something (an object, an idea, etc.). Sculpture is another prime example of this, as Renaissance master Lorenzo Ghiberti once remarked on how this art could only be captured through the feel of the form and the touch of the hand over the stone surface. In engineering, the design and construction of buildings, machines and structures are often noted to be more reliant on the manual and physical knowledge of mechanics than on abstract visuals or concepts (Ferguson, 1994). As such, physical action, feeling, and memory are inextricable from learning and thinking.

The second component of embodied thinking, empathizing, is defined as "imagining oneself in another's position, walking in their shoes, or feeling what they might feel" (p. 11). This is not restricted to other humans or even living objects. Empathizing is a concept we see enacted in the work of people across a variety of professions and walks of life. The very core of many creative professions requires empathetic thinking. Most writers must have empathetic skills to get into the minds and experiences of the people or characters that they write about – in order to imagine and depict them in compelling ways that ring true. For example, Charles Dickens was known to "write as if he were someone else", in order to develop empathetic identification with characters (Root-Bernstein & Root-Bernstein, 1999, pg. 182). This was also the case for Virginia Woolf, who as an author often would sit and look at something or someone for a long time, while holding her writing in her hands, until she felt "at one" with it.

The best dancers must have more than steps and techniques to convey their art in compelling ways and they must understand movement in the style of a character or a physical body that is not their own. The very foundation of dramatic work is empathy, as actors and actors have to empathize with their characters in order to understand them and relate them to an audience. For example, actors such as Daniel Day-Lewis and Dustin Hoffman are known for their immersive techniques, in which they "become" a character by learning their skills or absorbing their behaviors and gestures, instead of merely "acting like" a character (Root-Bernstein & Root-Bernstein, 1999, pg. 183).

But again, empathetic thinking is not restricted to the arts or humanities – it crosses into varied disciplines. And these ideas of bodily thinking or empathetic immersion lie at the heart of the example of Barbara McClintock we discussed above. We argue, however, that these ways of thinking are valuable not just to Nobel laureates and other exceptional thinkers but to a variety of applied professions as well.

Constructing the World through Embodied Ideas

When an architect designs a building there is more to the process than simply dividing the floor space between the required rooms and connecting them. The architect must consider how the space is to be used, how its inhabitants will interact, what the passerby will see, and how many other human experiences will take place within this space. They must construct something that coincides with the physical experiences of its inhabitants – something that is more than a box to store things. This is a space in which people will spend a portion of their lives. An architect must imagine the seemingly small details of a doorway; imagine and understand how walking through that doorway will feel. She may recall past experiences in other spaces, whether they are visual, physical, or emotional, and isolate the senses and stimuli that prompted the experience. She will consider how the structure of a hallway affects the flow of traffic, how this flow will determine where visitors will direct their gaze and how choice of materials for a railing will evoke a physical feeling of warmth or safety. These are not considerations found within software or in a collection of building codes. These are the considerations, both remembered and imagined, but most importantly *felt*, that come from the physical experiences sensed within other structures and spaces. This process demands that the architect do more than simply recall sensations. She must move through the structure in her mind, feel what it is like to be in this space, and experience how each of the senses will be affected. She can attempt to determine these things while sitting in an office chair, but it is far more likely that she will need to physically walk through similar spaces, observe and feel how her body moves in the space, put herself in others' shoes to imagine how people experience it differently, and build a wide array of physical bodily experiences to pull upon. It requires both thinking and feeling the way through the space, and placing oneself in another's shoes. It requires body thinking and empathy. As any construction project progresses the structure takes shape and the changes are made once the designers or inhabitants begin to walk through the shell of the space and observe how it feels. They are thinking through movement, both real and imagined. This type of thinking, in which the whole body is engaged, is what we mean by embodied thinking. Embodied thinking is reflective of the natural mind-body connection that characterizes how human beings think and operate in the world. It reflects the way that we experience space and how we connect our own feelings and experiences to things outside of ourselves. While it is a natural mode of thought, it is also one that has been frequently dismissed through much of the history of human psychology and learning – in favor of pure abstraction or the notion of the "intangible" mind. To help train people to be effective and creative thinkers, we must begin to focus more on how this skill functions, and provide students with knowledge and practice for embodied thinking.

Embodied Thinking for Creative Education

For educators, some of these concepts touch on known pedagogical methods and activities. And given the validity of embodied thinking across so many disciplines, it is essential that the skill be integrated into K-12 curriculum at multiple levels. In our Masters in Educational Technology program at Michigan State University, we teach a course entitled "Creativity in Teaching and Learning", in which the students (who are also practicing teachers) do just that. The course focus is on developing both the personal and professional creativity of the students using the trans-disciplinary skills mentioned previously. This intentional focus on the skills is meant to push students to deeply integrate them into their own classroom practices and lesson designs. We have found through our students' work examples of how embodied thinking can be used across subject matters; and we include a few examples to illustrate this below.

In our first example, an elementary teacher noticed how students sometimes struggle with a sense of numbers, how they are altered by addition and subtraction, and especially how negative numbers are conceptualized. She enacted a lesson in which students moved along chalk number lines to enact the processes of addition and subtraction, sensing the greater movement for larger changes in number. Examples of this are noted in figure 1 on the following page.

Of special interest was how she could use an everyday object, a set of stairs, to demystify the concept of positive/negative numbers, again through the use of movement. Students can again add and subtract, noticing how the numbers on each stair change as they move up and down, with the zero being at the top of the landing and negative numbers progressing down the stairs. This example is shown in the figure 2on the following page.

The students not only perceive the continuum of numbers along these scales, they take part in a physical process as part of mathematical operations. Those familiar sensations of running, hopping, or walking are tied to a concept they are attempting to make sense of in the classroom.

Another teacher chose to have the students listen to an audio recording of Poe's *The Tell-Tale Heart*, with her observing their reactions and prompting them to share their felt experiences afterward. One of the groups of students did this in their typical classroom settings, while two other groups did so with the lights dimmed. She described the group in the lighted room as having a slight reaction and finding the narrator "creepy", but provided a more extensive description of the classes in the dark room:

Figure 1: Students using a chalk line for addition and subtraction.

While playing the story, I noticed that many of my students began to cross their arms, almost hold themselves. Some girls made grimace faces and opened their eyes at gory descriptions. At a moment when the heart beat sound became too repetitive and too uncomfortable a boy stood up and asked to step out. After the story, a boy joked that he wanted to call his mom. I had my students reflect on what they felt so I got answers that are more honest. Some of the responses I received included "I felt cold", or "I wanted to move, or leave."

In this course on creativity for teachers, the projects that we see from our students revealing a range of applications for embodied thinking across many subjects. We have briefly noted two here that focus on mathematics and literature, yet it is clear that embodied thinking has a central place in any conception of education, given its value to exceptional thinkers in many different disciplines.

Combining the Mental, the Emotional, and the Physical

While many people may be familiar with the term or concept of bodily thinking, it is often an idea that is used in a somewhat more straightforward way – such as getting up and moving and stretching to wake the mind and stimulate thought; or it is associated with more obvious physical/mental activities such as dance or athletics. And while these are certainly aspects of embodied thinking, they don't cover the full range or depth of what is meant by the term – either in the range of subjects and disciplines that involve body thinking or in considering how the mind and body shape each other's learning and how ideas are "felt" in the body.

The field of embodied cognition has been key to recognizing what most of the history of human psychology and learning has ignored – that the mind and body are inextricably linked. Ideas, learning and knowledge arise from our physical experience in the world and in turn our mental life shapes what we physically perceive. One of the most famous and creative thinkers of all time, Albert Einstein often noted his own tendency for what we might now term embodied thinking. Despite his place as a landmark thinker in physics, he often noted that his abilities for pure mathematics (though quite competent) were not as developed as some of his contemporaries. What he excelled at was the "thought experiment", in which he imagined certain conditions or empathized with particles or processes to try to experience things (in imagination, both physically and mentally). For example, he pretended to be a photon traveling at the speed of light, and then envisioning what he felt, and what he saw. Then he became a second photon, further imagining what he could understand of the first one. It was this imagination of the physical and empathetic experience of being and acting as a particle (not pure mathematical thinking through equations), which led Einstein to the theory of relativity.

Figure 2: An example of stairs used to represent a number line.

Musical feeling, manipulative ability, imaginative empathy, and physical sensations all reside at the core of embodied thinking. As a trans-disciplinary skill, it is an acknowledged method by which skillful thinkers and creative people perceive their world and create across disciplines. To ignore or exclude embodied thinking in favor of abstract thinking, or pursuit of "pure knowledge", is to miss out on the opportunity to tap into one of the most natural ways of thinking that humans possess.

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