New Insights from Embodied Cognition About Children's Learning of Language and Concepts

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On May 6 and 7, 2019, the Werklund School of Education at the University of Calgary held a Play and Literacy Think Tank with support from an SSHRC connection grant, the University of Calgary Vice President Research and the Werklund School of Education. Approximately 40 teachers, early childhood educators, facilitators in outdoor and indoor physical literacy and active lifestyle, and researchers gathered to listen to world-renowned scholars Bryan Kolb, PhD, Sebastian Suggate, PhD, and Magdalena Janus, PhD, speak about brain development (Kolb and Gibb 2011), the impact of play and fine motor skills on learning (Suggate, Stoeger and Pufke 2017), and current Canadian measures of kindergarten readiness as measured by the EDI (Guhn et al 2016). This paper was inspired by discussions of that event.

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Recent years have seen fairly dramatic changes in our understanding of the mind and brain. Our current understanding may differ from what teachers learned about the mind and cognition in an introductory psychology, educational psychology, developmental psychology or even a cognitive psychology course. In the current article, as researchers in cognitive psychology and particularly in language processing, we consider what recent research shows about how the mind works and describe the implications this may have for teaching.

The Role of the Body

It is not hard to imagine that a child learns their first words through bodily experiences with their environment, and research provides extensive evidence for this (Smith, Maouene and Hidaka 2007). A baby puts objects in their mouth, holds things, moves them around and touches them. Even a very young baby lying on the floor sees a mobile and bats at it with their hands.

FIGURE 1. A baby holds and puts things in their mouth to help learn first words, for example, *sock*.

This way of experiencing the world through the body is at the heart of the theory of *embodied cognition*, the notion that our knowledge and our representations of concepts are a direct result of our physical experience with the environment (Wellsby and Pexman 2014a). Embodied cognition has changed the way we see the human mind and how we understand children's learning of language and concepts.

Embodied cognition represents a shift in our understanding of the mind because it is a stark departure from earlier theories of cognition. The traditional view of cognition characterized thinking

as the manipulation of arbitrary symbols, representing information much like a computer (Fodor 2008; Pylyshyn 1985). In order to explain the capacity for human language, it was proposed that the mind hosts a language system separate from the sensory and motor systems (Chomsky 1976). In contrast, the embodied cognition view explains much of human language capacity through common sensorimotor systems. The same sensory and motor systems that we use to experience the world are recruited when we store and retrieve information in the mind, whether language information, visual information or emotion information. The mind is characterized as multimodal, using information from sensory, motor and language systems together, and it is this multimodality that supports our cognitive functions.

In short, embodied cognition says that the sensorimotor systems are more important for cognition than was previously thought (Glenberg 2015). In the following sections, we will discuss how the body connects to experiences in the environment, development of children's fine motor skills, and how children's physical skills can shape their cognition and therefore influence learning. We will also discuss the role of the body in children's early word learning and how that contributes to the concepts they develop. We will then discuss the role of embodied cognition in reading comprehension. Finally, we will give a short summary of the main points from the article and implications for teaching and learning.

Sensorimotor Development

In early development, children play and manipulate objects in their environment. These experiences are crucial for the child's visual system to form shape-based categories. Children distinguish objects from each other based on visual shape, and then learn object names that map onto and help refine those categories (Smith 2013). Thus, early object recognition builds a child's early vocabulary (Pereira, Smith and Yu 2014) and begins to lay the foundation for later learning; vocabulary learning is a key predictor of academic success (Hjetland et al 2019).

This relationship between sensory experience with objects and language learning is reciprocal: while identifying the object helps the child learn the label, learning the label for the object also teaches the child to pay attention to the shape of the object and helps create experiences necessary to develop the child's visual object recognition system. This creates a multimodal system in which a young infant uses information from various subsystems: motor, vision, audition; the overlap and coordination of these systems and many more components in the larger neurocognitive system become the drivers for cognitive development (Smith 2013).

FIGURE 2. Forming categories based on shape.

The emergence of the theory of embodied cognition has led researchers to examine more carefully the links between the physical world, children's actions with their hands and body, and the consequences for children's cognition. For young children, play has been shown to be the instrument to create this interaction between the body and language learning. Play, while not easy to define, is commonly agreed to be any activity that is self-motivated, involves active involvement and creates a joyful discovery (Yogman et al 2018). Play promotes not only current language learning but also future language learning. During play, and specifically pretend play, children practise their ability to recognize basic categories; for example, knowledge of *hat* allows a child to make substitutions—for instance, using a pot as a hat. This ability to substitute one object name for another is predictive of children's vocabulary learning (Smith 2013), and early vocabulary learning causally predicts later language development (Hjetland et al 2019).

So, while a child is pretending to be a princess in a castle or a truck driver at a construction site, they are learning and experimenting with essential vocabulary, which predicts their later language learning and can even predict their future reading comprehension ability (Castles, Rastle and Nation 2018; Duff et al 2015; Nation and Snowling 2004). This vocabulary goes beyond the words for the objects with which a child interacts. The child's interactions and the labels used to describe those interactions also contribute to their verb learning and their acquisition of adjectives (Wellsby and Pexman 2014a).

FIGURE 3. Experimenting with essential vocabulary: making a pretend car out of boxes and paint.

The Advantage of Sensorimotor Vocabulary

Thus, sensorimotor experience with objects and events in the world helps children to develop vocabulary skills. Embodied cognition explains this quite easily: sensorimotor experiences are the building blocks of language and cognition. This is also evident in the fact that some words are easier to learn and remember than other words. For example, children and adults can more easily recognize and remember words that are associated with mental imagery, like *kite* and *cake* (Inkster et al 2016).

These imageability effects are thought to be due to high-imagery words having richer sensory representations in the brain. In addition, our research group has found that children and adults also recognize words more readily when those words refer to things that a person is likely to have a lot of motor experience with, like *phone* and *chair* (Inkster et al 2016; Wellsby and Pexman 2014b). These studies have shown that we can respond faster and more accurately to words that refer to objects we can easily interact with using our body than to words that refer to objects we do not interact with as easily (for example, *nest*, *ship*).

FIGURE 4. Children can more easily recognize words that refer to things they can picture (for example, cake) and with which they have a lot of motor experience (for example, chair).

The idea that sensory and motor experiences influence the way we learn words and concepts and also the way we later think about and remember those concepts is consistent with the tight relationship that embodied cognition proposes between mind and body. This idea has been further examined by studying the role of fine motor experiences in early childhood, to try to understand how those experiences might shape learning and cognition.

Fine Motor Skills Support Academic Development

While motor development and language skills have typically been examined separately, Suggate, Steoger and Pufke (2017) showed that fine motor skills are critical for academic development in early childhood and are related to children's literacy skills, mathematical achievement and overall cognitive achievement. Fine motor skills are "small muscle movements requiring close eye-hand coordination" (Luo et al 2007, 596) and can include dexterity, the skillful manipulation of small objects. Fine motor skills also include graphomotor skills—the skills involved in combining input from visual and motor modalities such as drawing and writing—and speed-dominated fine motor skills such as key-tapping (Martzog, Stoeger and Suggate 2019). In addition, Pexman and Wellsby (2016) found some evidence that there is a relationship between children's manual dexterity and their speech skills.

FIGURE 5. Turn taking and learning: a child-led activity removing lids from milk jugs and putting them back on while taking turns with a parent.

Suggate and Stoeger (2014) reported numerous links between children's fine motor skills and their cognitive skills. For example, there are reported relationships between children's fine motor skills, like peg moving, and their reasoning and memory abilities, and between children's pattern copying and block arrangement and their general school readiness. Thus, there is some support for the idea that cognitive development does not occur in isolation from motor development. Further, children's language skills have been found to play a critical role in their early math skills (Slusser, Ribner and Shusterman 2019). As a result, Suggate and Stoeger (2014) argue that children should be given ample time to engage in activities that develop their language skills and also activities that develop their motor skills. For example, children continue to need active play time (opportunities to move around the classroom, physical education classes, recess time) in addition to focused literacy time (listening to stories, practising reading or writing, working at literacy centres). Opportunities to engage in both activities, for example, acting out a favourite story such as "The Three Little Pigs" or "Henny Penny," can engage both language and motor skills at the same time.

Suggate, Stoeger and Pufke (2017) examined how the specific activities in which children engage are related to early childhood development. They found that engaging in activities during the preschool years such as art experiences and crafting (operating scissors, drawing, weaving and playing with small toys—for example, Lego and other building toys) was related to preschool children's fine motor development at the start of kindergarten.

FIGURE 6. Fine motor skills in preschool—for example, Lego, crafting, scissor skills

In turn, children's acquisition of fine motor skills at the start of kindergarten is related to several later cognitive achievements, such reasoning, memory, and acquisition of knowledge and skills (Martzog, Stoeger and Suggate 2019; Suggate, Stoeger and Pufkin 2017). This relationship is specific to fine motor skills and not true of other motor skills (for example, gross motor). Therefore, there is evidence that children's fine motor skills not only support important graphomotor skills necessary for classroom activities such as writing but are also linked to broader cognitive skills necessary for all classroom activities and for general learning. While there is evidence for relationships between children's fine motor skills and their cognitive and academic development, we should note that the picture is complex.

Our research group has examined the linguistic and cognitive skills involved when children learn new vocabulary. We have also looked at whether certain characteristics of the words' meanings (that is, emotion, imageability, concreteness) facilitate acquisition. We have found in some studies that children's fine motor skills do not directly relate to *every* aspect of their language development (Lund, Sidhu and Pexman 2019). We have speculated that some underlying skills such as executive function, attention and sequencing are common among these domains and help contribute to the observed relationships between fine motor skills and cognitive skills (Pexman and Wellsby 2016).

Sensorimotor Processing Supports Reading Comprehension

The *simple view* of reading was originally conceptualized by Gough and Tunmer (1986), and they argued that reading comprehension includes both *decoding*, or identifying words in print, and *linguistic comprehension*, characterized as the

understanding of spoken language (Nation 2019). All readers need to be able to identify individual words *and* derive meaning from the text. These two component skills have been shown to explain a large amount of the variance in children's reading comprehension, and it is important to understand how the component processes work and develop to optimize children's reading and language instruction (Nation 2019). The child's sensorimotor experience has been shown to have an impact on both these components of reading development.

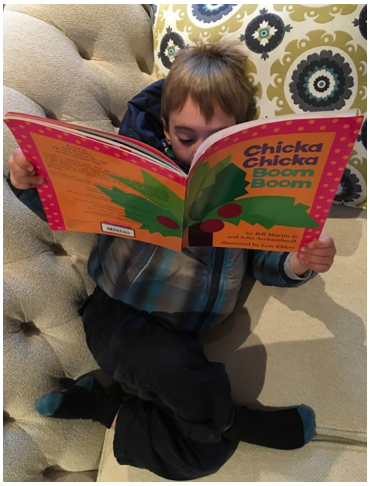

FIGURE 7. Learning to read involves both decoding the individual words and deriving meaning from the text.

Decoding

Learning to read necessarily requires children to explicitly be taught how to crack the alphabetic code. Children need to learn that patterns of lines, curves and dots match onto specific letters, which map onto sounds, which can be blended together and mapped onto meaning (Castles, Rastle and Nation 2018). Castles, Rastle and Nation (2018) provided evidence that without explicit teaching, children will not detect the alphabetic principle and need training both to break down words into their sounds and to map them to the graphic symbols (sound–letter correspondences).

Decoding involves individual letter recognition, and research suggests that embodied experience is important to children's mastery of letter recognition (James and Engelhardt 2012). James and Engelhardt taught prereading children to produce letters and simple shapes by printing free form, tracing or using single-key typing. Next, the researchers measured children's brain activation using neuroimaging (functional magnetic resonance imaging [fMRI]). During the fMRI session, the children passively viewed the letters and shapes they had learned along with additional letters and shapes that had not been included in the training. This allowed the researchers to see how the children's brains responded as a function of the method they had used to produce the letter. Their results showed that the part of the brain known as the *reading circuit* was activated only for letters produced during the free-form printing task and not for letters produced during tracing or typing. The results suggest that children's visual processing of the letters is influenced by their motor experience: the act of printing a letter leads to brain changes not seen from tracing or typing (James and Engelhardt 2012). These findings provide evidence for the influence of the child's sensorimotor experience on their learning of individual letters.

In the early stages of reading development, children need support and training to learn how the code works for their language. Once they have at least some rudimentary decoding skills, the path to becoming a skilled reader involves developing the ability to recognize words accurately and easily. However, there is much evidence that even skilled readers continue to use the alphabetic principle (Pexman, Lupker and Jared 2001). This transition from slow tentative reader, sounding out every sound, to fluent reader involves *exposure*. Children need to build expertise through experience with print and learn to be both *precise* (that is, to know the exact spelling) and *flexible* (that is, to be able to adapt to different print–meaning combinations). As children become more proficient, cognitive resources are freed up for comprehension (Castles, Rastle and Nation 2018).

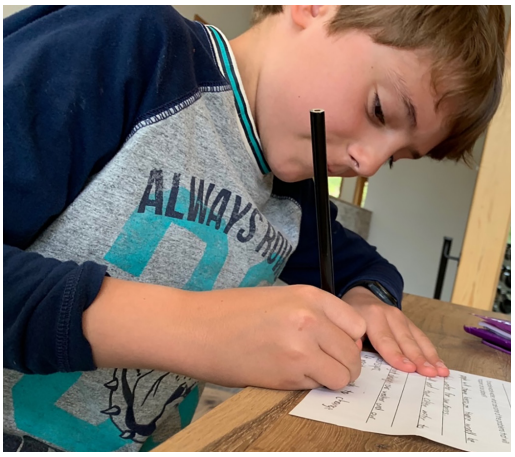

FIGURE 8. A child who practises printing by hand (not on computer or by tracing) builds valuable connections with the reading circuit.

The connection between sensorimotor abilities and decoding is emphasized in a number of existing training programs. For instance, in the Lively Letters program (Telian and Castagnozzi 2001), each phoneme is given an action, eliciting a

relationship between the sound the letter makes and a body action. For example, the *u* letter that makes the sound /ʊ/ as in *up* has a *U* with the vertical lines or "arms" of the *u* designed to look like a baby's arms reaching up; the teacher says "/ʊ/ … /ʊ/ … up, just like the baby reaching up to get out of his crib." These types of action connect sensorimotor experience to decoding skills. Another example from current teaching practice is the use of sandpaper letters typical of a Montessori teaching environment (Ginns et al 2016).

Listening Comprehension

In addition to decoding, a child needs to derive meaning from the words they read in order to achieve successful reading comprehension. A child's reading comprehension is tied to their linguistic comprehension and vocabulary development (Castles, Rastle and Nation 2018; Nation 2019). Many experiments demonstrate that children's sensorimotor experience can scaffold their comprehension abilities during reading (Glenberg, Brown and Levin 2007; Glenberg, Goldberg and Zhu 2011; Glenberg et al 2004; Marley, Levin and Glenberg 2010). For instance, based on the theory of embodied cognition, Glenberg et al (2004) predicted that there would be positive effects on children's recall and application of material read if children were explicitly taught to manipulate toy objects in order to enact events described in text. When compared to a group of children who simply reread the text, the children in the manipulation group had better recall and memory of the stories they read. Glenberg et al (2007) also found that the enactment strategy could be equally effective for enhancing reading comprehension in small groups. Recognizing the logistical difficulty of having to provide a classroom full of children with toys for every possible storybook, Glenberg, Goldberg and Zhu (2011) extended these findings to a virtual environment, by having Grade 1 and 2 children manipulate images of toys on a computer screen. Results showed that children's reading comprehension was improved just as much by virtual manipulation as by physical manipulation of the toys. Glenberg inferred that this was because virtual manipulation provides sufficient enactment through mental imagery and simulation to support comprehension. This suggests an important use of educational technology to enhance early reading comprehension.

Overall, reading comprehension is complex and multifaceted and so is reading instruction (Castles, Rastle and Nation 2018). Castles, Rastle and Nation recommended a number of strategies, including text discussion with peers and teachers, chances for clarification, summarization, and question generation. The most recent iteration of the *simple model of reading* highlights the complexity and interplay between reading comprehension, decoding and oral language comprehension, with these component skills all feeding forward and backward, resulting in both positive influences and negative influences depending on the child's individual abilities in each domain.

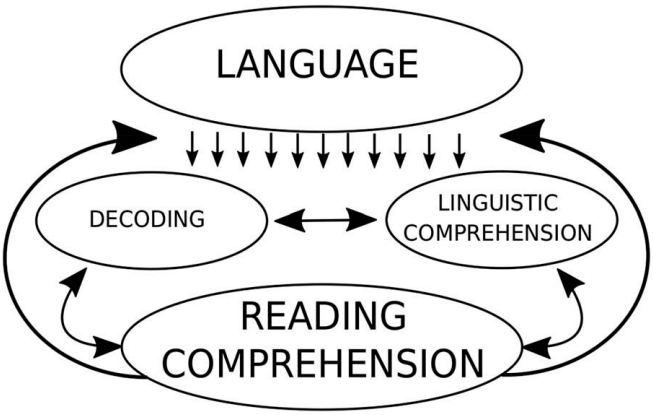

FIGURE 9. An expanded view of the simple view of reading (Nation 2019).

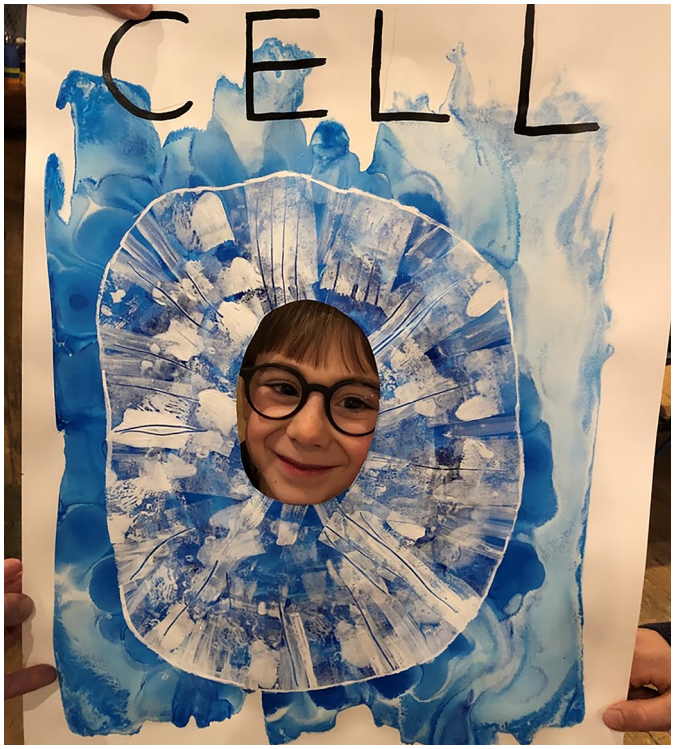

FIGURE 10. Becoming a cell after reading *Cells: An Owner's Handbook* (Fisher 2019). Reading aloud with children can include reading the story and acting out key parts, in addition to text discussion, clarification, summarization and discussion of new vocabulary.

What Embodied Cognition Has Not Explained

Embodied cognition is a promising theory that has a number of implications for teaching, but it is important to note that it has not explained everything. For instance, a challenge for the embodied cognition framework is to explain how children learn abstract words. These are words that refer to concepts that we cannot see or touch. Abstract words include emotion words such as *anger* and *joy*, ideas like *friendship* and *freedom*, and descriptive qualities such as *brilliance* and *honesty*. Abstract words are important for education (Beck, McKeown and Kucan 2013; Biemiller 2012). They are necessary for communication and learning, because they are ubiquitous in scientific (for example, *hypothesize*, *evaluate*, *adaptation*), mathematical (for example, *subtraction*, *compare*, *prediction*) and cultural (for example, *identity*, *belief*, *values*) language (Fang 2005). Importantly, Ponari, Norbury and Vigliocco (2018) described a burst in children's abstract vocabulary that seems to occur around Grade 2. Embodied cognition assumes that sensorimotor processing is essential to learning concepts and language, so if children cannot see or touch abstract concepts, how do they learn abstract words? A recent study by Vigliocco, Ponari and Norbury (2017) provides a few clues. The results suggest that children rely on multiple strategies when they are first learning abstract words. Emotion words are some of the first abstract words that children learn, and it is possible that children's emotion systems allow them to grasp these meanings (for example, learning the meaning of *love* by associating it with the feeling of being hugged) (Vigliocco, Ponari and Norbury 2017).

Indeed, emotion information seems to be important to children's processing of abstract words (Lund, Sidhu and Pexman 2019; Ponari, Norbury and Vigliocco 2018), at least early in development (prior to age 9). Once some abstract words have been learned, children may be able to learn more of them by connecting new meanings to the other words they know, but we need more research in this area to determine the factors at play in later vocabulary development.

We know from recent research in cognitive psychology that vocabulary learning is crucial for later academic success. Multiple longitudinal studies involving randomized control trials have shown that children's oral language skills at age 4 can significantly impact their language skills and reading comprehension at age 7 (Hjetland et al 2019). At the same time, Fricke et al (2017) showed that children's language and reading outcomes can be affected by language interventions, including the use of narratives, vocabulary and listening skills, and that these interventions can be effectively delivered by multiple providers, including teachers but also parents (Burgoyne et al 2018). The research we have reviewed here shows that vocabulary can and should be taught in multimodal ways. Recent research has shown that shared book reading and guided play can be equally effective at increasing vocabulary (Lawson-Adams et al 2019).

FIGURE 11. Emotion is one way a child learns the meaning of abstract words.

The shift we have seen in cognitive psychology, from describing the mind as an amodal system, like a computer, to an embodied system in which, at least to a certain extent, our sensorimotor experiences, emotions and body states can influence and support our learning, could be important to think about while teaching and when applying learning principles across the curriculum. As teachers can attest, teaching is not about turning on or off switches in the child's brain, but rather is about engagement of the child's body, mind and experiences. Recent developments in cognitive science support teaching strategies that engage the whole child through play, movement, acting, critical thinking, exploratory learning and systematic pretend play (Hopkins, Dore and Lillard 2015).

Take-Home Messages

- Children learn their first words through their bodily experiences (seeing, mouthing, touching, and holding objects).
- The theory of *embodied cognition* describes the notion that our knowledge and concepts are a direct result of our experience with our environment. This is important for learning.
- Children's early environmental experiences—the people in their life (mom, dad, auntie, nanny, early childhood educator), the food and drinks they enjoy (water, milk), and objects and materials in their day-to-day life (blanket, teddy, bottle, toys, mirrors, sand)—influence their early vocabulary, and vocabulary is a key predictor of academic success.
- As children continue to build vocabulary, play experiences are integral; motor experiences with objects help children learn vocabulary even beyond their immediate needs. The sensory and motor experiences that enable children to learn words will also influence the way they later think and remember these concepts.
- Fine motor experience (small muscle movements [using] hand-eye coordination) is also critical for academic development, and children's fine motor skills are related to their literacy skills, mathematical achievement and overall cognitive development.
- Children's sensorimotor experience has also been shown to have an impact on both letter decoding and reading comprehension. Gaining experience printing letters free form and manipulating toys and objects can facilitate better recall and memory for the letters they learn and the stories they read.
- Abstract words, which refer to concepts that we cannot see or touch (*friendship*, *brilliance*, *joy*), are harder to experience through the body but show a burst in development around age 8. Early learning of abstract words seems to be tied to the child's emotional experience and then later tied to other words they know.
- Vocabulary can and should be taught in multimodal ways.
- Overall, the view from *embodied cognition* is that the mind is multimodal and this multimodality (using our body, vision, hands) supports learning.

Such strategies support the child's learning of new material, and also support the fundamental nature of their cognition—the way they learn, not just their learning at that moment.

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