Constructivism + Embodied Cognition = Enactivism: Theoretical and Practical Implications for Conceptual Change

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Available at: https://works.bepress.com/edtechdev/16/
AERA 2010 Conference:  
**Constructivism + Embodied Cognition = Enactivism:**  
Theoretical and Practical Implications for Conceptual Change

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**Objectives**

The objective of this paper is to explore specific theoretical and practical implications of recent research on embodied cognition and enactivism for the design of effective learning environments, especially those targeting conceptual change. The ultimate goal is to illustrate how enactivism and embodied cognition can help meet the criteria that often define scientific progress (Laudan, 1977), for the purpose of advancing educational research and development and constructivist theory. Namely, embodied cognition and enactivism may:

- explain specific anomalies and inconsistencies in the data from experimental research on conceptual change and learning
- suggest bridges for theoretical divides in conceptual change research (Vosniadou, 2007)
- suggest innovative new instructional techniques
- explain previously unexplained yet successful learning strategies and techniques
- remove the need for certain theoretical constructs
- and, provide a new foundation for existing theories of learning and cognition that suggests new lines of empirical research

**Theoretical Framework**

Research on embodied cognition and the theory of enactivism have found that sensory behavior and cognition are connected, if not inseparable (Gibbs, 2005; Kiverstein & Clark, 2009; Gangopadhyay & Kiverstein, 2009). The implications of this research have been well explored in other fields such as cognitive science, linguistics, human-computer interaction, developmental psychology, mathematics, biology, artificial intelligence, history, and even philosophy and law. The implications have not been explored as much in education, however, with the exception of math education. This paper explores the implications of enactivism for constructivist theory, and the implications of embodied cognition research for theories and research on conceptual change.

**Constructivism**

Constructivism, as espoused by such researchers and theorists as Jean Piaget and Ernst von Glasersfeld, has dominated educational research and practice for over 20 years. In this theory, learning is considered an active process in which a learner constructs his or her own subjective knowledge. Learners accommodate and assimilate new knowledge into their existing knowledge base.

Some of the new ideas, positive contributions, and implications of the constructivist worldview for education include:

- Teaching and learning become more student-centered. Learning does not automatically happen when information is presented to a student.
• Education becomes more humanized. Students are not just machines to be programmed.
• “If we assume that students have to build up their own knowledge, we have to consider that they are not ‘blank slates’” (von Glasersfeld, 1991, p. 9).
• Students are rational beings: “Whatever a student says in answer to a question (or “problem”) is what makes sense to the student at that moment” (ibid, p. 10).
• “If teachers want to modify a student’s concepts and conceptual structures, they have to try and build up a model of the particular student’s own thinking” (ibid, p. 10).
• “Asking students how they got to the answer they gave” (ibid, p. 10) is useful for pedagogical purposes.
• Letting students struggle with problems of their own choice, helping them (as Maria Montessori said a long time ago) only when they ask for help” (ibid, p. 10).
• “Under the umbrella of ‘constructivism’ the definition of a powerful learning environment has changed dramatically: we do not regard homogeneous grouping as the norm, but diversity comes into play as an asset. Cooperative learning is promoted and teaching is considered as a co-construction in which active participation of the learner is essential” (Kumpulainen, 2008, p. 90).

Constructivism has not been devoid of criticism, however. Some criticisms may include:
• “If all cognition (and even perception) is active, then even rote learning must be active. It, too, must represent some kind of construction” (Noddings, 2006, p. 127).
• Piaget focused too heavily on an individual person's interactions with objects (not people). This led to the development of social constructivism as one offshoot of constructivism.
• The difficulty of assessment: How do we know what students understand? “It is no use simply telling students that they are wrong” (von Glasersfeld, 1991, p. 13). When asked what are the implications of constructivism for how we assess student learning, von Glasersfeld responded “This is the most difficult question.”
• Traditional and radical constructivism considers conceptual knowledge to be rational/linguistic. From the Constructivist Journal homepage (http://www.univie.ac.at/constructivism/journal/): “Constructivist approaches can be said to differ also with respect to whether constructs are considered to populate the rational-linguistic (e.g., von Glasersfeld, Schmidt), the biological-bodily (“enactivist/embodied” theories, e.g., Varela), or the social realm (social constructivism, e.g., Latour).”
• Some educators may have a “romantic” notion of constructivism, and/or conflate constructivism with pure unguided discovery learning. Constructivist-inspired educational approaches such as problem-based learning and simulations still require a significant amount of guidance and structure – either from the instructor/facilitator (Hmelo-Silver & Barrows, 2006) or embedded in the learning environment (de Jong et al., 1999; de Jong & van Joolingen, 1998). And adopting constructivist approaches does not mean abandoning lectures or direct instruction, which can still be highly effective, especially after students have experienced some constructivist exploration activity, such as a lab or simulation or exploring data (Brant, Hooper, & Sugrue, 1991; Schwartz & Bransford, 1998).
• The learning paradox: How is new knowledge “constructed”? Von Glasersfeld (1998) responded to this paradox by incorporating Peirce’s abductive reasoning and Piaget’s scheme theory to explain how learning occurs in constructivism.
• Epistemological and grounding problems. What is the nature of this knowledge? What is the relationship between this knowledge and the world?

Enactivism does not have a solution for all these criticisms and issues, but it does make some progress.
Relation between enactivism and constructivism

One of the founders of enactivism, Humberto Maturana, has long been a colleague of Ernst von Glasersfeld, who developed the radical constructivist perspective, and in fact Maturana is on the advisory board of the *Constructivist Foundations* journal which has published articles on enactivism (McGee, 2005, 2006; Kenny, 2007). Proulx (2008) has suggested that one might view enactivism as an extension of constructivism, although there are significant differences, as well.

**Enactivism.** In enactivism, thinking and cognition are *grounded* in bodily actions: “it is not knowledge-as-object but knowledge-as-action” (Begg, 2000). As Reid (1996) notes in distinguishing constructivism from enactivism, “It is not a matter of an individual having a cognitive structure, which determines how the individual can think, or of there being conceptual structures which determine what new concepts can develop. The organism as a whole is its continually changing structure which determines its own actions on itself and its world” (p. 2). Already, this view that concepts have an embodied basis can help explain some of the alternative conceptions researchers and educators have uncovered in students: “naive notions like those derived from bodily metaphors may underpin misconceptions, such as the quasi-Aristotelian notions that Alternative Frameworks researchers in science education have documented extensively” (Ernst, 2006). These implications are specifically explored further in the latter half of this paper.

Potential benefits and contributions of an enactivist, embodied worldview on education.

- Enactivism and embodied cognition research provide a theoretical grounding as well as a more solid, concrete, empirical foundation for some of the concepts to come out of cognitive science and constructivism (Pecher & Zwaan, 2005; Barsalou, 2008). Enactivism removes the “inside/outside” distinction present in most constructivist theoretical writings, for example.
- Considerations of embodiment perhaps humanize students and learning even more than constructivism – for example, the embodied notion of empathy and its role in learning and understanding (Cunningham, 2009).
- “Learning environments that do not support students’ use of body and gesture can limit what and how they learn” (Roth & Lawless, 2001).
- “What is called teaching, therefore, involves not only the words and sentences a teacher utters and writes on the board during a lesson, but also all the hands/arms gestures, body movements, and facial expressions a teacher performs in the classroom” (Pozzer-Ardenghi & Roth, 2006, p.96)
- One cannot ignore the the embodied nature of teaching and learning, including in online learning contexts (McWilliam & Taylor, 1998; Bayne, 2004; Dall'Alba & Barnacle, 2005).
- “It is a mistake to treat knowledge and ideas as if they are detached from embodied encounter with the world” (Yates, 2007, p. 773, discussing O'Loughlin, 2006).
- “Teaching and learning practices that attend directly to sense making could assist in the learning process” (Barnacle, 2009, p. 31).
- “Learning must attend ultimately not only to the intellect but the whole person, and therefore, to transforming who we are as people” (ibid, p. 32). “Our present education may transform into the education of how to become a human being, instead of only a citizen” (Jörg, 2009, p. 4).
- Educational technology: With a better understanding of the constraints of embodiment, one can better evaluate the pedagogical implications and limitations of new technologies, such as 3D multiuser worlds (Second Life), tablet computers (such as the iPad), smart phones (iPhone, Android phones), and so forth. Educators considering embodiment have also taken the lead in...
designing new enactive and embodied interfaces for instruction, such as microcomputer-based labs and sensors (described further below), rather than always being in a reactive, consumer mode with respect to new technologies.

Enactivism and embodied cognition, like constructivism and cognitive research, are not devoid of real and potential criticisms and limitations, however.

Potential criticisms, limitations of, or constraints on enactivism and embodied cognition for education.

• There are many notions and examples that stretch the notion of “embodiment” - including 3D avatars, physical actions, presence, social embodiment, and issues of gender and identity. Wilson (2002) discusses several related but differing views on embodied cognition, and many lump together situated cognition and distributed or extended cognition with embodied cognition, as well.

• One must be careful of oversimplifying applications of embodied cognition or enactivism to the design of learning environments. Embodiment does not simply or only boil down to techniques such as using anthropomorphic representations (such as pedagogical agents), making something “hands-on,” using gestures, or being physically active during learning and teaching.

• In fact “limited interactivity may sometimes be more effective than full interactivity” (Keehner et al., 2008, p. 1128). This paradox is explained further in the “action-under-constraint” section later in this paper.

• Embodied cognition and enactivism are not behaviorism. Embodied cognition does bring back the “baby” (embodied actions and behaviors) that was thrown out with the “bath water” (black box stimulus-response models) during the cognitive revolution against behaviorism (Byrne, 1994). Proulx (2004) describes two crucial differences between enactivism and behaviorism, however. Actions become a focus again because physical (embodied) processes and mental processes are assumed to be one and the same, not because of an assumption that mental processes are impossible to access or do not exist (behaviorism). Second, behaviorism assumes a direction of causation from environment to animal (behavior), whereas enactivism sees individuals as continually changing themselves, with a reciprocal relationship between the body and the world.

Techniques and Modes of Inquiry

The remainder of this paper will re-visit existing empirical research studies and theories related to conceptual change, for the purpose of exploring how embodied cognition research can help provide better explanations or explain anomalies or inconsistencies in the data.

Evidence

Explaining Anomalies and Inconsistent Data.

Below are just a few examples of the kinds of anomalies and inconsistent educational research findings for which embodied cognition and enactivism may suggest explanations.

Intuitive physics, physics education. A common theory explaining the misconceptions students have about projectile motion is that they hold a naïve impetus theory of the motion and also that their misconceptions derive from the particular visual point of view they take when viewing or imagining a dynamic scene. When viewing an animation of a ball dropping from a airplane, for example, a
significant percentage of students later draw the path of that ball as having fallen straight down rather than in the correct, parabolic path. McCloskey et al. (1986) manipulated this animation to make the ball fall in various paths that were behind or ahead of the correct parabolic path. When students drew what they saw, their drawn paths were shifted backward in line with the theory that they were taking a visual perspective of the scene from the point of view of the airplane – in which the ball looks like it is falling straight down in the canonical path. However, there was one exception, or anomaly. When the animation was altered such that the ball fell ahead of the correct path during a normal drop, students correctly drew the actual path of the ball dropping. In this case the ball landed ahead of the plane. Even though from the visual perspective of the plane, the ball only moves forward a small amount, students drew the correct path in which the ball moved forward that small amount plus the distance that the plane traveled. When viewing this particular animation, the ball may appear to shoot out from the plane, or be thrown ahead from the plane, rather than being passively dropped. A question is do students conceive of a scenario as a ball as falling passively, or as a person actively throwing a ball? Note this is no longer a question of visual perspective, but embodied perspective.

The visual perspective explanation of related misconceptions about project motion has other anomalies as well. In the curved tube problem, students are asked to draw the path a ball takes after exiting a curved tube. A significant percentage of students believe the ball keeps curving after exiting the tube. Furthermore, in a hands-on condition students were asked to make puck move through a curved tube shape on top of a table, and they would often move their hand with a circular motion (winding up) before releasing the puck as if to make the puck curve. There is no purely visual experience or explanation that would explain this behavior, and neither is there a purely logical or abstract conceptual theory that might explain why students believe the object travels in a curvilinear path absent external forces or constraints. A better explanation may come from embodied theories of cognition, in which students may be re-conceptualizing both physical and more abstract physics concepts in terms of actions and manually-controlled changes to behavior. We've all seen or experienced similar phenomenon in sports, when for example a baseball player hits a homerun and leans his body or waves his arms as if to attempt to control the path of the ball, or after hitting a pool ball with the cue one leans over or pushes the stick in a futile effort to alter the path of the ball. The point is that our everyday conceptions of physics are not only non-Newtonian, but not solely visual, either. We hold an embodied physics that has been explored quite in depth by perception and action researchers over the past two decades. For example, when viewing a dot travelling across a computer screen at a constant velocity, we do not see it as such (Runeson, 1974). It appears to move faster at the edges of the screen and slower in the middle, partly because of our saccadic eye movements which are jumping back and forth from the edge of the screen and the dot on the screen to judge velocity.

Animations and diagrams. In more generally-relevant recent research on animations/videos and diagrams, studies are finding that animations and videos depicting dynamic processes aren’t inherently more effective than static diagrams for learning purposes. In fact on average, diagrams have a slight edge (Tversky et al., 2002). Part of this is because with diagrams one can take one's time, explore and revisit different parts of the diagram, “mentally animate” what’s going on, and so forth. When watching a video or animation, it may go too fast for someone (or too slow), and one might miss or not understand part of it. However, what has been shown to be even more effective than either option (video/animation or static diagrams) are user-controllable diagrams, or animated, controllable simulations (Lowe, 2004; Chan & Black, 2006). If students are allowed to control the movement of an object, for example, or the changing of a variable, their scores and other measures of understanding are much higher than from passive animations or static diagrams alone.

Other anomalies. Other sources of anomalies and inconsistencies in data from various educational
research studies include research on cognitive load theory, which itself was altered to add the concept of 'germane' cognitive load after anomalous data emerged. Attempts to apply symbolic, information processing cognitive models to this data has met certain limitations which may be overcome by the application of embodied cognition.

**Bridging Theoretical Divides, Revisiting Old Theories**

Various theoretical disputes and arguments exist in the education research literature, as well. Sometimes the competing models may not have considerations of embodiment which could provide new insights. Also, sometimes educational and cognitive theories fall out of favor more because of their age or because they lack a grounding that embodied cognition and enactivism might help provide.

**Conceptual change theories.** Two dominant, yet competing perspectives on the nature of conceptual change and students' intuitive knowledge have emerged over the last 30 years. Misconceptions theory, as represented by Micheline Chi, and p-prims theory (“knowledge in pieces”), as represented by Andy diSessa. Tuminaro (2002) provides a succinct summary of the two perspectives: “In short, the unitary story of knowledge [Chi] is that students possess robust cognitive structures, or misconceptions, that need to be torn down, so the correct conception can be erected in its stead. The manifold framework [diSessa] claims that students possess small pieces of knowledge that have developed through everyday reasoning about the world” (p. 15). Embodied cognition and enactivism holds promise for finding connections and bridges between these two perspectives, if not providing a new and better theory of conceptual knowledge. What the core phenomenological primitives in diSessa's theory (such as 'force as mover' and 'force as action') and the 'treat like a substance or object' misconception in Chi's theory may have in common is that action is at the core. Actions are both theory-like (Chi), in that they are coordinated and it is difficult to alter ingrained patterns of actions, but they are also contextualized. The diSessa perspective neglected that the body is a part of the context, too - not just a context but every learning context, and it is shared between contexts, lending to its potential role in transfer and abstract learning. We also tend to break up complex dynamic systems into chunks that can be enacted (such as turning one pulley at a time in a pulley system or turning one gear at a time).

**McLuhan's media theory.** Examining the theoretical literature, there appears to be a connection between enactivism and Marshall McLuhan's ideas about media, which have been applied to education by numerous researchers and educational theorists. Radical enactivists (such as Daniel Hutto) reject the notion of “content” of experience, or that experiences are kinds of “objects.” Instead experience is thought of in terms of actions done by or to the expericer. McLuhan espoused that the “content” of media was the audience itself. Of course his most famous quote was that “the media is the message,” and the embodied version might be that “the body is the message.” In the context of education, this is referring to the bodies of the students and the teacher. As mentioned before, the embodied context of teaching and learning should not be ignored even, or especially, in online learning contexts (McWilliam & Taylor, 1998; Bayne, 2004; Dall'Alba & Barnacle, 2005).

**Other examples.** McVee et al. (2005) described how considerations of embodiment can help bolster schema theory and its applications to and explanations of reading comprehension. The motor theory of speech perception was developed in the 1950s and later fell out of favor after the emergence of newer cognitive linguistic and speech theories. However, it is seeing renewed interest in part due to recent research in embodied cognition and enactivism.

**Explaining Previously Successful Techniques**
Embodied cognition research can also help explain other existing instructional strategies and techniques that have been successful.

**Microcomputer-based laboratories (MBL) and graphs of motion.** MBL involves the use of sensors connected to a computer, such as distance, motion, and temperature sensors. The computer graphs and analyzes the data from the sensors in real time. For example, a student may move a toy car back and forth along a track, while a computer instantly displays a graph of the car’s position or velocity or acceleration by interpreting the data from an optical distance sensor pointed at the car. From such an activity, a student may develop a “tool perspective,” or a perspective on how the computer is interpreting the motion of the object and translating it into a graph (Nemirovsky, Tierney, & Wright, 1998). Students often have misconceptions about graphs of motion, such as confusing slope with height or interpreting a graph as a picture of the motion it represents, i.e., believing that a graph line goes up and then down like a hill depicts the motion of an object going up and over a hill (Clement, 1989). Yet after only a matter of minutes interacting with a microcomputer-based lab, students may show marked improvements in their graph interpretation skills (Brasell, 1987). Brasell’s study also showed that a group of students who had MBL feedback delayed a mere 20-30 seconds showed much diminished performance compared to students who received immediate feedback. The real-time feedback alone though does not completely explain the remarkable learning effects. An alternate technique to MBL is interactive video instruction (IVI), in which a video of the motion of an object is shown in real-time and linked to a graph of the object’s motion. This technique does not show the learning advantages that MBL shows, however. Beichner states that with IVI, “students cannot control the motion. This ability to make changes – and then instantly see the effect – is vital to the efficacy of MBL. The feedback appeals to the visual and kinesthetic senses” (1990, p.812). Thus real-time kinesthetic interactions are important to the success of MBL. More recent studies have confirmed the significance contribution embodiment and bodily interactions have in understanding graphs of motion (Botzer & Yerushalmy, 2008; Anastopoulou, Sharples, & Baber, 2010).

**Participatory simulations.** The use of strategies to support kinesthetic participation with symbolic simulations has not been specifically studied, although researchers have found evidence linking students’ kinesthetic behavior to their understanding of dynamic systems. Monaghan and Clement (1999) observed students performing hand motions and visualizations while using a relative motion simulation, and they interpreted this as evidence for “self-projection,” or students forming their own mental model of the scenario. Roth and Lawless (2001) also observed that students’ “gestures are an important means in the construction of perception and communication as students interact over and about a computer software environment,” and as mentioned before, they suggest that “learning environments that do not support students’ use of body and gesture can limit what and how students learn.” Sadler, Whitney, Shore, and Deutsch (1999) allowed students using a simulation of wave mechanics to interactively control and generate simulated wave behavior, but did not explore the effect these interactions had on student understanding specifically. Students did enjoy however being able to create their own representations of wave phenomena in addition to exploring the examples included with the software.

The nature of a computer-based simulation allows for strategies to assist learning with understanding that are more interactive than direct instruction, visualization, or animation. A student may interact with a simulated system in real time. Furthermore, a student may reconnect to a system in the most direct sense by becoming a participating agent within that system. While participation has always integral to experiential simulations in which students take on the roles of human agents within a system, symbolic simulations that support interactive participation, termed *participatory simulations* (Colella, 2000; Wilensky & Stroup, 1999), have been rarer.
In an example of a participatory simulation, a class of tenth grade biology students each wore microprocessors known as Thinking Tags developed at the MIT Media Lab (Colella, 2000). These embedded computers contained infrared transmitters and receivers and a display containing a number pad and five bicolor LEDs. Through group activities with these devices, a teacher could simulate the spread of a virus with the students. A certain student’s computer may initially be “infected” with the virus, and students who come in contact with that student may also be infected. Wilensky and Stroup (1999) have also conducted participatory simulations of traffic patterns using networked calculators instead of Thinking Tags.

Research with participatory simulations is only in initial phases, but students appear to have a high level of engagement with the experience and collect evidence and form hypotheses about the underlying rules of the simulation. This research has only been concerned with one type of system, however, decentralized systems. In this type of system many similar or identical agents act independently of one another, and the underlying rules governing behavior may be very simple although the resulting patterns of behavior may be very complex. Participatory simulations help students gradually discover the simple rules underlying complex systems, but learning about decentralized systems can also be facilitated without the use of computers. In another version of the simulation of a virus spread, students are each given a small cup of clear liquid, one of which is “infected” with the base compound sodium hydroxide. After mixing liquids with one another, students test their own cup of fluid with litmus paper to discover who has been contaminated with the base (Hammer, 2001). The use of Thinking Tags and networked calculators can help improve the speed and precision of a participatory simulation of a decentralized system, but participatory simulations can support learning about physical systems in which different components do not behave so independently, as well. I have labeled the latter “enactive modeling,” as described below.

Contrasting cases. Contrasting cases are another highly effective instructional strategy that facilitates learning in virtually any domain using any media (text, diagrams, pictures, animations, etc.). Contrasting cases help students notice new features and make distinctions (Bransford et al., 1989; Schwartz & Bransford, 1998). Using this strategy, one shows learners two or more related cases at a time, rather than one at a time. Essentially one can direct attention to a feature by showing two cases side by side that differ by that very feature on which attention needs to be focused. Contrasting cases has been shown to be an effective strategy in other domain areas such as algebra (Rittle-Johnson & Star, 2007; Derry, Wilsman, & Hackbarth, 2007) and psychology (Schwartz & Bransford, 1998).

One basic example of contrasting cases described in Bransford et al. (1989) is to imagine viewing a circle on the left side of a screen. Students viewing this circle are asked to describe what they see, and may notice that it is a circle. Now, if other students are shown the same circle in the context of another, different circle on the other side of the screen, they additionally notice features that distinguish the two circles. For example, if the other circle has a thicker border, or is smaller or larger, or is moved to a different position, or has a different color, and so forth.

An embodied theory of what may be happening with contrasting cases is that students are mentally doing the transformation that causes the two objects to differ. This simplifies how we can understand the two objects, as just one object plus a transformation. Hahn, Chater, and Richardson (2003) developed a cognitive model in which we make all similarity judgments via transformations. This model could easily be extended to a more embodied notion of “transformation” as being connected to manual processes of transforming objects and embodied concepts.
Other existing techniques. The list of existing techniques that could perhaps be better explained by appealing to concepts from embodied cognition and enactivism is too long to review here. Some might include the Montessori methods (Lillard, 2008), effective “chalkboard” interactions via gestures (Goldin-Meadow, 2003; Pozzer-Ardenghi & Roth, 2006), reading strategies for young children (Glenberg et al., 2004), and techniques in various sub-domains such as music education (Antle et al., 2009).

Innovative New Instructional Techniques

In the first two examples above, MBL and participatory simulations, there is one limitation: the mapping between actions and concepts is usually very literal, direct, and spatially isomorphic. These are concrete mappings of actions to concepts. However, as Lakoff and Johnson and others have shown, even the most abstract of concepts have an embodied basis, including even those in math and philosophy (Johnson, 1990; Lakoff & Nuñez, 2001; Lakoff & Johnson, 1999). One does not need to limit the applications of embodied action or bodily motion to literal concepts that map directly and concretely as in the examples above. One can utilize embodiment for helping to teach, explain, or understand abstract concepts, especially those that are often not completely or accurately described by visualizations or words alone.

Enactive modeling and user-controllable diagrams and animations. In previous research I have described the technique of enactive modeling, in which a student does not merely observe a dynamic system, but takes over the role of one of the elements and re-enacts and controls its behavior, observing the effects on the rest of the system. This and related instructional strategies have proven more effective than traditional instruction using static diagrams, animations, or verbal/oral descriptions. In one study, students took on the role of the voltage source. This allowed them to take a voltage-centered perspective on circuit behavior (as experts do) and enact different circuit behaviors directly, such as “wiggling” voltage back and forth to simulate AC circuits and see the effects of voltage frequency and amplitude in circuits with different configurations and components such as inductors and capacitors.

Action-under-constraint. There is a potentially more generalizable instructional design strategy than the ones above, inspired by embodied cognition and enactivism. It is not ones actions per se that one learns when interacting in a learning environment, but the constraints on our actions that we “internalize,” in the Vygotskian sense. And this assumes that the constraints on action are aligned with the constraints of the system or concepts being learned. This is not always the case, however, and may explain certain ineffective practices and misconceptions. An example using the “airplane drop” problem from conceptual change research is described below. This “action-under-constraint” framework can be boiled down to a strategy that is an extension of the instructional maxim from cognitive and constructivist research known as “making thinking visible” or the “make it visible” strategy. The new, embodied, twist on that strategy is to “make it enactable” or “make it doable.” Making something visible is sometimes, but not always, enough to let students inspect a model or system and understand its constraints. Making something visible and manipulable, however, can often better facilitate conceptual understanding, especially students with lower spatial and visualization abilities.

Conclusions

Embodied cognition research and enactivism may serve as a new foundation for research on conceptual change and constructivist-inspired learning environments. I do not believe this involves throwing out or superseding constructivist theories at all. There may even be an opportunity for
developing a “super-parent” model for instructional design that can find connections or situations in which either or multiple behaviorist, cognitivist, and constructivist instructional strategies may be appropriate. This is due to the fact that embodied cognition brings back the baby (embodied actions) that was thrown out with the bath water (black box stimulus-response models) during the cognitive revolution which rejected theories from the behaviorist era (Byrne, 1994). This doesn't mean behaviorism is back or that embodied cognition and enactivism are the same thing as behaviorism, however. Proulx (2004) has discussed the differences between enactivism and behaviorism in more detail.

Significance of this Work

This paper provides specific examples and clear theoretical suggestions to help other educational researchers and developers create more effective learning environments that foster conceptual change. New lines of research and theoretical inquiry inspired by embodied cognition and enactivism could further improve student learning and teacher training.

References


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