Embodied Design: 
Developing a Research Program

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“Embodied Design in Interaction”
Universiteit Utrecht
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\[ f(k; n, p) = \binom{n}{k} p^k (1-p)^{n-k} \]
I can’t make sense of this!

This makes no sense to me!

What is this?

What in the world is this?

What does this mean?

Why do you believe this?
What is the use of all these symbols?

\[ f(k; n, p) = \binom{n}{k} p^k (1 - p)^{n-k} \]

Where do we begin?
What is the use of all these symbols? Why not begin by showing children the real thing so that they may at least know what you’re talking about?

As a general rule—never substitute the symbol for the thing signified, unless it’s impossible to show the thing itself; because the children’s attention is so taken up with the symbol that they will forget what it signifies.
How do we engage children in interesting activities that will give rise to meaningful learning of big ideas they should understand and use, if they are to flourish in our wonderful, complicated world and make it a better place for themselves as well as all of us?
"The most usable meanings are those that are richly connected with imagery action and that tie into other meanings."

Pat Thompson, 2013
“What is the use of all these symbols? Why not begin by showing children the real thing so that they may at least know what you’re talking about?

As a general rule—never substitute the symbol for the thing signified, unless it’s impossible to show the thing itself; because the children’s attention is so taken up with the symbol that they will forget what it signifies.”

Jean-Jacques Rousseau

*Emile, Book III, 1762*
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Jean-Jacques Rousseau

*Emile, Book III, 1762*
thing → symbol

\[ f(k; n, p) = \binom{n}{k} p^k (1 - p)^{n-k} \]
Embodied Design


END
OF
THE
WORLD
Enactivism
(Varela, Thompson, & Rosch, 1991)

• “In a nutshell, the enactive approach consists of two points:
Strategies for Making Green Additive Multiplicative?

Attentional Anchor
A Collaborative Construct

  *Phenomenology and the Cognitive Sciences*

  *Educational Psychology Review*

- Abrahamson, Shayan, Bakker, & van der Schaaf (2016)
  *Human Development*

  *Journal of the Learning Sciences*

  *Cognitive Research: Principles & Implications*

- Duijzer, Shayan, Bakker, van der Schaaf, & Abrahamson (2017)
  *Frontiers in Psychology*

- Shvarts & Abrahamson (under review)
  *American Educational Research Association*
Let’s make a circle!

Let’s make a circle!

Movements

• Distal movement
• Proximal movement
• Sensorimotor scheme


Constructing movement in mathematics and dance: An interdisciplinary pedagogical dialogue on subjectivity and awareness.


www.TinyURL.com/DorAmi2017
The phenomenon of movement:
• conceptualize phenomenology of movement
• theorize individual awareness of movement
• understand mechanisms of guided movement

Intellectual foundations:
• Feldenkrais Method
• Constructivism
• Enactivism
• Systems Dynamics
• Sociocultural Theory
Perception is...

- Active (not passive)
- Constructed (not inherent)
- Relational (not monistic)
- Subjective (not objective)
- Tacit (not conscious)
Perception is...
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- Relational (not monistic)
- Subjective (not objective)
- Tacit (not conscious)
Thoughts

• A growing conviction that our respective pedagogical worlds have much to share and debate
• Movement as an inherently polysemous ontology
• When mathematics learning is conceptualized as founded on sensorimotor entrainment, we share in pedagogical practices
  – center on subjective idiosyncratic phenomenology of movement
  – attempt to stimulate awareness of orientation so that students modify the action to accord with a normative or desired cultural practice

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13 Ways of Looking at Two Hands Moving

A Pairs Game

On the Polysemous Meanings of Movement
From attentional anchor point, LH & RH always on the same ray.
always double as high as LH
Your Mission, If You Choose to Accept It

- You have received your secret strategy
- Sit opposite your buddy, within reach
- Mirroring each other, enact the movement, each according to your own strategy
- Try to guess the other person’s strategy
  - You can hint, but no talking
- Perform A’s instructions together (4 hands), adjusting RH/LH so you are mirroring each other
- Now play it 2 hands (one hand each), only RH
Debrief

• How successful were you in guessing the other’s strategy?
• In particular, what were you doing to figure this out?
• What did you do in order to help the other person figure out how you were moving?
• How did you coordinate the mirroring?
• How did you coordinate the distributed co-enacting (one hand each)?
• What might be the relevance of this exercise for a research program to understand how people reason mathematically? How about design for learning?
• Can you think of a different concepts / movements that could be approached this way?
• What else, if anything, was interesting for you in this exercise?
Embodied Design

...is a pedagogical framework that seeks to promote grounded conceptual learning by creating situations in which students can be guided to negotiate tacit and cultural ways of perceiving and acting.
Parity as Epistemic Criterion for Appropriating Mathematical Forms

Perception-based design:

Action-based design:

thing                           symbol
thing                           symbol
Anne-Ciska Cuiper  
Marijke Veugen  
Loes Boven  
Carolien Duijzer  

COLLABORATING RESEARCHERS  
Rosa Alberto  
Shakila Shayan  
Arthur Bakker  
Marijke van der Schaaf  

AT UTRECHT UNIVERSITY
Action-Based Embodied Design: The Mathematics Imagery Trainer

- The design simulates naturalistic conditions for conceptual learning. The Mathematics Imagery Trainer creates a field of promoted action fostering the practice of culturally valued ways of moving.

- The designer instantiates a mathematical concept in the form of an information structure (system of functions).

- This information structure is programmed into a technological device as procedural rules.

- The information structure is latent to this device and becomes apparent and known to a person only through interacting with the device and reflecting on the interaction.

- The interaction is at an interface: a natural-user interface for human-computer interaction.

- The person interacts with the device by enacting physical movements in an attempt to satisfy prescribed task demands. The information structure privileges certain actions — physical postures and therefore movement regimes — over others as satisfying task demands; this bias is surfaced at the interface via rule-based real-time feedback on performance.

- The person discovers, constructs, regulates, and refines their own subjective means of enacting these movements, theorized as the emergence of a new sensorimotor scheme.

- The scheme is evident for observation as fluent information-invariant transformations of the environment.

- This scheme incorporates a new sensory structure orienting and coordinating the motor activity. We call this new sensory structure an attentional anchor (Hutto/Sánchez-García).

- The attentional anchor is the sensory component of the new affordance that the person comes to apprehend in the field of promoted action, that is, when engaging the technological device in the context of this task-based activity, and perhaps beyond.

- AA as self-imposed environmental constraint (“given that”) ; solution assimilated as task constraints (“even as I”).

- One might say that the new sensorimotor scheme, including the new attentional anchor, are the person's enactive incorporation of the design’s latent information structure.

Dor Abrahamson
Design-Based Research

• An approach to educational research, wherein practice of educational design serves as context for pursuing problems of importance to the science of learning.

• Research problems emerge where our intuition fails, the literature does not provide answers, and our colleagues are stumped. This happens during:
  – Ideation
  – Engineering
  – Data gathering
  – Analysis
Embodied Design

• An approach to educational design-based research that is both informed by embodiment theory and informing the evaluation and development of this theory

• Two design genres
  – perception-based design
  – action-based design
Embodied Design: Constructing Means for Constructing Meaning

• General Design Objective
  – Learners will accept mathematical forms as meaningful ways of thinking and acting

• Why do they accept the forms?
  – Perception-based design: *Inferential Parity*
  – Action-based design: *Functional Parity*

• What does parity do?
  – Parity is epistemic grounds for appropriating mathematical signification of embodied skill
Embodied Design as a Two-Step: **Elicit** Tacit Schema, **Signify** It Culturally

- **Elicit Subjective Meanings**
  - Pose perceptuo/motor problem
    - perceptual judgment
    - motor action
  - Encourage articulation

- **Signify Subjective Meanings**
  - Introduce new affordances: media, frames of reference, symbolic artifacts for enacting, explaining, evaluating
  - Encourage coordination with grounding meanings
“The great advances in science usually result from new tools rather than from new doctrines.”

Freeman Dyson, 1996
Mathematics Imagery Trainer #1

2:3 = 4:6

In search of an embodied design for proportional equivalence
Johnny Chung Lee
Enter Symbolic Artifacts

![Table Image]

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MIT-P for iPad

tinyurl.com/FreeMITP

tinyurl.com/FreeMITP
Gesture Enhancement of Virtual-Agents Mathematics Tutors

Gesture Enhancement of Virtual-Agents Mathematics Tutors

Meanwhile, in Utrecht...
Eye-Tracking Study: Parallel

Typical Eye-Tracking Patterns

A

B

C

D

E

A

B

C

D

E
Original Paper

Human Development 2015;58:218–244
DOI: 10.1159/000443153

Eye-Tracking Piaget: Capturing the Emergence of Attentional Anchors in the Coordination of Proportional Motor Action

Dor Abrahamsona Shakila Shayanb Arthur Bakkerb Marieke van der Schaaff

aUniversity of California, Berkeley, Calif., USA; bUtrecht University, Utrecht, The Netherlands
Eye-Tracking Study: Orthogonals
Typical Eye-Tracking Patterns
Dynamic Visualization Overlay
From ET Teaching to ET *in* Teaching?

**Abrahamson, D., Shayan, S., Bakker, A., & van der Schaaf, M. F.** (2016).
Eye-tracking Piaget: Capturing the emergence of attentional anchors in the coordination of proportional motor action. *Human Development, 58*(4-5), 218-244.
When Teachers Know a Task’s Attentional Anchors

Attentional Anchor
A Collaborative Construct

• Hutto & Sánchez-García (2015)
  *Phenomenology and the Cognitive Sciences*

• Hutto, Kirchhoff, & Abrahamson (2015)
  *Educational Psychology Review*

• Abrahamson, Shayan, Bakker, & van der Schaaf (2016)
  *Human Development*

• Abrahamson, D., & Sánchez-García, R. (2016)
  *Journal of the Learning Sciences*

• Abrahamson, D., & Bakker, A. (2016)
  *Cognitive Research: Principles & Implications*

• Duijzer, Shayan, Bakker, van der Schaaf, & Abrahamson (2017)
  *Frontiers in Psychology*
Thank You

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Dynamic-Systems Approach to the Development of Cognition and Action

Specific motor problems are in many cases called to the infant's attention or even thrust upon the infant by one or more caretakers in what we call a field of promoted action. It is because human adults promote specific motor problems for infants—often before the child is capable of solving that problem—that human action development takes the course that it does.

Try This at Home!

**STRETCHING**

1. month

2. month

3. month

**SUSPENSION**

4. month

5. month

6. month

Fig. 2. Bambara baby gymnastics. This drawing illustrates some of the kinetic manipulations and massage techniques used widely among the Bambara for young infants.

Interim Summary

1. The body is not a mere input/output device – the body is not just an executioner of disembodied cognitive inferences and directives: the body plays an intrinsic role in cognition – cognition is embodied.

2. The body is in an environment, an ecology with built-in constraints, e.g., its own biomechanics, or gravity, and these constraints create for the agent emergent problems to solve; the solution of these problems, if practiced repeatedly and under varying conditions, can become part of the agent’s operational repertory, e.g., walking.

3. Humans can create specific conditions for other humans to experience and solve problems, so that those younger humans are acculturated to participate in vital practices.
Repetition Without Repetition

“Repetitions of a movement or action are necessary in order to solve a motor problem many times (better and better) and to find the best ways of solving it.”

“...[D]uring a correctly organized exercise, a student is repeating many times, not the means for solving a given motor problem, but the process of solving it, the changing and improving of the means.

“The fact that the ‘secrets’ of swimming are not in some special body movements but in special sensations and corrections explains why these secrets are impossible to teach by demonstration.”

Functional Integration

MF: "Without conscious attention to what one is feeling during an action and without applying the attention directly to the entire movement resulting from these actions, no development will occur—simple mechanical repetition will never make this come about."

Carl Ginsburg: “Learning itself is not conscious. The integration process itself is not conscious. Nevertheless the process depends on conscious processes in feeling and detecting changes. The consequence is felt as difference.”

MF: “[T]he use and experience of the body are necessary to form mental functions. After the formation of a sufficient number of paths and patterns, the somatic support becomes less and less essential; we can think—that is, re-excite the formed patterns, regrouping them into new ones. “

Every thought associated with movement induces on its own a certain preliminary straining of a corresponding muscular system that tends to be expressed in movement. If it remains only a thought, then since this movement is not brought to fruition and is not disclosed, it remains concealed in an entirely tangible and effectual form.

Even the most abstract thoughts of relations that are difficult to convey in the language of movement, like various mathematical formulas...., even they are related ultimately to particular residues of former movements now reproduced anew.

[T]hought [is] the first two-thirds of a mental reflex, or as a reflex that has been broken down up into two-thirds, having in mind a reflex that is not brought to fruition, that is inhibited in its external aspect.

Summary of Theoretical Introduction: Implications of Kinesiology for Embodied Learning

- Motor learning is a process of problem solving
- Motor learning creates refinement or reorganization of neural connections
- Motor dexterity is the sum total of automatisms the agent learns to enact so as to optimize performance given unexpected constraints
- Motor dexterity develops via the agent’s explorative interaction in material ecology, sometimes via social intervention
- Motor competence cannot be taught directly – we can only create ecologies – fields of promoted action – wherein we govern constraints
- Motor learning emerges – body as vanguard, adapting to unexpected changes, discovering affordances; post facto consciousness to differences
- New coordination patterns as cognitive vehicles of reasoning
Conclusions

(a) From a systems perspective, learning is the development of new coordination dynamics among student, task, and environment

(b) Students develop sensorimotor schemes as their pragmatic solutions to designed interaction problems

(c) The ‘sensori-’ component of the scheme is a new attentional anchor, i.e., a real or imagined object, area, or other aspect or behavior of the perceptual manifold that emerges to facilitate motor coordination; and

(d) Introducing symbolic artifacts both elicits new affordances for students’ motor control of the environment and, in so doing, shifts students’ discourse into explicit mathematical re-visualization of the environment.

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Investigative Approach: Design-Based Research

Conjecture-driven, iterative, empirical studies, wherein theory and design co-inscribe
Embodied Design:
Constructing Means for Constructing Meaning

Experience first, analyze later:
Building mathematical concepts from perception, action, aesthetics, and common sense

- Friedrich Fröbel (b. 1782)
- Maria Montessori (b. 1870)
- Hans Freudenthal (b. 1905)
- Caleb Gattegno (b. 1911)
- Zoltán Diénès (b. 1916)
- Seymour Papert (b. 1928)

Embodied Mathematical Reasoning

Terrence Tao, MathOverflow