Object Manipulations and Gestures Can Enhance STEM Learning

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The Potential of Embodied Cognition to Improve STEAM Instructional Dynamic Visualizations

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Abstract An embodied cognition perspective recognizes that the evolution of the human mind has been shaped by the evolution of the species’ whole body in its interaction with the environment. For example, hand actions—such as object manipulations and gestures—have been fundamental for human survival, and thus they continue to trigger different areas of the evolved mind. One of these areas is the mirror neuron system, a major processor of bodily movement, which allows humans to learn manipulations and gestures with relative ease. A clear implication for instruction, across many Science, Technology, Engineering, Arts and Mathematics (STEAM) topics, is to profit from the effortless nature of hand actions in order to enhance the learning of difficult concepts or challenging educational materials. One example of demanding instructional materials is dynamic visualizations (e.g., animation, video), which can be too transient to follow, understand and learn from. However, we argue that dynamic visualizations may overcome the transience problem by including embodied activity. In this chapter, we will review a diverse number of studies that show the instructional benefits of embodied cognition, manipulations, and gestures. Specifically, we will address how these evolved skills can be employed to effectively learn from STEAM dynamic visualizations.

Keywords Embodied cognition · Biologically primary ability · Manipulation · Gesture · Static versus dynamic visualization · Spatial ability
Outline

- Transient Information Effect
- Embodied Cognition (Human Hand Actions)
- Hand Actions, STEM, and Spatial Ability
- Hand Actions and STEM
  - Manipulations and STEM
  - Gestures and STEM
- Visuospatial Abilities
- Hand Actions and Visuospatial Abilities
  - Manipulations and Spatial Ability
  - Gestures and Working Memory
- PAI Project
- Instructional Implications
Transient Information Effect

- **Cognitive load theory**\(^{(1)}\)
  - We have a limited working memory
  - Applications for multimedia learning\(^{(2)}\)

- **Transient information effect**
  - Three simultaneous cognitive tasks in working memory\(^{(3,4)}\)
    - Process the current visible information
    - Remember the previous elements (no longer visible)
    - Integrate both streams of information in order to comprehend the material

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Embodied Cognition

• Cognition is embodied or grounded\(^{(1,2)}\)
  • Connected to the environment
  • Connected to the body
    • Human hand actions in object manipulations and gestures

• Evolutionary educational psychology\(^{(3)}\)
  • Biologically primary abilities
    • Evolved and effortless
    • Learned outside of institutions
  • Biologically secondary abilities
    • Not evolved and effortful
    • Learned inside the institutions
  • Use primary abilities to foster secondary abilities

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Hand Actions, STEM, and Spatial Ability

Manipulations and STEM

- Positive effects for object manipulations
  - Doing the manipulations\(^{(1)}\)
  - Observing others doing the manipulations (e.g., in visualizations)\(^{(2)}\)

- Concrete versus abstract manipulatives
  - Concreteness fading\(^{(3)}\)

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Gestures and STEM

- Positive effects for gestures
  - Doing the gestures\(^{(1)}\)
  - Observing others doing the gestures (e.g., in visualizations)\(^{(2)}\)


Gestures and STEM

Visuospatial Abilities

- Working memory includes a visuospatial subcomponent\(^{(1)}\)
- The subprocessor is related to spatial ability\(^{(2)}\)
  - “Skill in representing and transforming symbolic or nonlinguistic information through space.”\(^{(3)}\)
- Commonly measured spatial abilities are mental rotation and spatial visualization\(^{(4)}\)


Manipulations and Spatial Ability

- Manual and mental rotations
  - Computerized manual training with 3D shapes\(^{(1)}\)
  - Females (not males) benefited:
    - > scores on MRT
    - > perceived playfulness

Gestures and Working Memory

- Doing gestures (pointing) to explain equations\(^{(1)}\)
  - Working memory measured with a dual task
  - Gestures benefitted those with low working memory capacity

PAI Project

• Females tend to underperform in
  • STEM areas
  • Visuospatial abilities

• Experiment to compare
  • Scores in computer visuospatial tests
  • For
    • Males (M) versus females (F)
    • STEM students (S) versus non-STEM students (nS)

• Hypotheses
  • H₁: M > F
  • H₂: S > nS
  • H₃: MS > FS > MnS > FnS
PAI Project

- Mental Rotation
PAI Project

- Visual Memory Span
  - Visual patterns task\(^{(1)}\)

PAI Project

• Spatial Memory Span
  • Corsi block test(1)

PAI Project

- Visuo-spatial working memory
  - Dual tasks\(^{(1)}\)

Instructional Implications

- Primary abilities can foster learning secondary STEM abilities
  - Doing and observing object manipulations
  - Doing and observing gestures
- Visuospatial abilities
  - Are important for STEM and primary tasks
  - Tend to be underperformed by females
- Current project
  - Measuring computerized visuospatial abilities
  - Investigate effects of gender and STEM versus non-STEM disciplines

Thank you!