Do tangible interfaces enhance learning?

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Existing work on tangibles

- Lots of technical development and design work
- Descriptive frameworks
- Link with embodiment
- Collaboration

Learning with tangibles

- Need for empirically-grounded frameworks
- Need to know:
  - What are the cognitive and social effects of tangibles
  - Whether and why they might promote learning
  - What features of tangibles might be important to learning (and which are incidental)
  - What domains should they be used in

‘Framework’ on tangibles and learning

- Review of the literature on tangibles and in cognitive science, psychology and education
- Six themes:
  - Possible learning benefits
  - Typical learning domains
  - Type of learning activity
  - Integration of representations
  - Concreteness and sensori-directness
  - Effects of physicality
- Aims to highlight trends in work on tangibles, link to related research and point to directions for future work

Possible learning benefits

- Learning benefits of physical manipulation
  - Embodiment
  - Piagetian psychology
  - Physical manipulatives
- Collaboration
  - Shared space
  - Gaze/gesture monitoring
  - Increased awareness of others' activity
  - Situated learning
  - Concurrent interaction
    - (but see Stanton & Neale, 2003)
  - Manipulation of objects outside interactive space

Possible learning benefits

- Accessibility
  - Young children
  - People with disabilities
  - Novices
- Novelty of links
- Playful learning

- Promising, but little empirical validation
- Q: is there something specific about tangible interfaces that leads to these learning benefits?

Typical learning domains

- Variety of learning domains supported by tangibles
- Some repeatedly seen
  - Narrative
  - Molecular biology/chemistry
  - Dynamic systems
  - Programming
- These domains tend to be inherently spatial
  - Literally (e.g. molecules)
  - Metaphorically
- In 2D spatial representations, what does tangibility provide?

Types of learning activity

- What kinds of activity might be supported by tangibles?
- Mellar and Bliss: learning with scientific models
- Exploratory learning
  - Investigating a model created by a domain expert
  - Learning through discovery and cognitive conflict
  - Why tangibles?
    - If more intuitive or natural interaction
      - Maximum attention on learning domain, rather than system
    - If effects of physical interation
      - Extra or different info might be gained

Types of learning activity

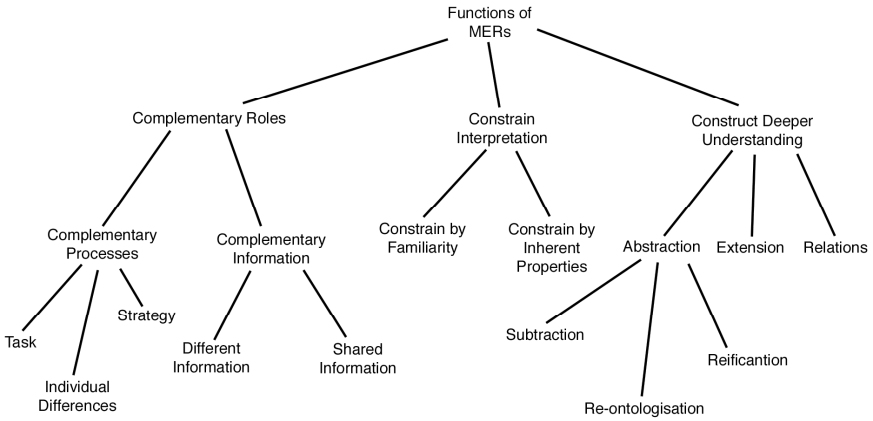
- Expressive learning
  - Learners create an external representation of a domain
    - cf. constructionist learning (Papert, 1980)
  - Includes system generated representations
    - E.g. logs of user activity
    - Working with external representations might aid reflection and link abstract knowledge with personal experience
  - Why tangibles?
    - Can record aspects of physical activity
    - Novel representational media

Integration of representations

- Taxonomic work highlights degree of integration of physical and digital components
- Little guidance as to potential benefits
- Suggest looking to more general work on external representations
- Highly integrated
  - Cheng (1999) Law encoding diagrams
    - Semantic transparency
      - integrate levels of representation
      - Combine globally homogeneous with locally heterogeneous representations
      - Integrating perspectives
    - Plastic generativity
      - Malleable meaningful expressions
      - Compact sequences of procedures
      - Uniform procedures

Integration of representations

- Low integration
  - Ainsworth (1999; 2006) multiple representations



Concreteness and sensori-directness

- Physicality and concreteness often conflated (Clements, 1999)
- Discussion of tangibles often emphasises ‘ready-to-hand activity (e.g. Dourish; cf. Chalmers (2005)
- For learning, present-at-hand activity important too
  - Practical attention to how to use the interface
  - Theoretical on the structure of the learning domain
- Both abstract and concrete representations can be of benefit
  - Concrete can lead to increased task performance
  - Abstract can result in better learning transfer
- What benefits will come from different combinations of abstract/concrete physical and digital representations?

Effects of physicality

- Physical action can influence cognition and vice versa
- Potential for physical activity to influence learning
- Few empirical tests of effects of physicality (separate from concreteness)
  - Klahr and colleagues: no physicality effect
- Few comparative studies of tangible vs graphical interfaces
  - Fails et al. Hazard room study
    - No differences found
  - Rogers et al. colour mixing study
    - More reflective discussion for novel transforms

Conclusions

- Need for empirical work to test potential benefits
  - We can't just assume learning benefits of using physical objects
- More investigation of learning domains that go beyond 2D space
  - E.g. texture, malleability
- More focus on learning activities
- Guidance for design of representations
  - High integration (Cheng, 1999)
  - Low integration (Ainsworth, 1999; 2006)
- Concreteness and sensori-directness
  - Separate from physicality
  - More attention to 'presence-at-hand' for learning
  - Abstract and concrete representations can both be of benefit
- Effects of physicality
  - Influence on e.g. attitudes, spatial processing
  - Need evidence for effect on learning