Understanding (and transforming) multi-representational learning

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My Assumptions

- Learning is increasingly representational
  - We don’t learn from direct experience but from its representation (often in visual form)
- Learning with representations is multi-representational
  - A representation is rarely alone!
- Learning should lead to representational competence:
  - Learners should be able to understand, select, explain, critique and even invent representations
- Visual learning is an intertwined process: learning with and about representations simultaneously
  - Learners (definitionally) don’t have complete domain or representation knowledge
Twin foci

- Research should do more to understand how to design representations:
  - when and for whom particular (combinations of) representations will be beneficial
- AND how to use them effectively
  - Uncover how best to support learners to make meaning from multiple representations
Inspirations: Theories and theorists

- External and Display Based Reason Theorists
  - E.g. Larkin and Simon, Zhang, Rogers

- Embodied & Perceptual Symbol Theorists
  - E.g. Barselou, Goldstone

- Socio-cultural Theorists
  - E.g. Vygostky, Saljo

- Semantic Theorists
  - E.g. Stenning

- Semiotic and Social Semiotic Theorists
  - E.g. Peirce, Kress, Lemke

- Modality Theorists
  - E.g. Mayer, Sweller, Schnotz, Paivio
Fake Tag Cloud

Semiotic

Social Semiotic

Socio-Cultural Theory

External

Embodied

Semantic

Constructivist

Modality
Oxygenated-blood then flows into venules, which merge into the pulmonary veins that lead to the left atrium of the heart.

Blood from the left ventricle enters systemic circulation through the aorta.
Multiple representations over multiple modes
Multiple Representations of Estimation

Maths

Pictures

Mixed

Cognitive Tasks (in this case)

- Learners should understand
  1. the properties of the representation
  2. the relation between the representations and the domain
  3. how to translate between representations
Why does this help us understand blood flow through the heart?
Why show a picture?

- To take advantage of perceptual processes (Larkin & Simon, 1986)
- Too off load cognition into the world and reduce demands on working memory (Zhang & Norman, 2004)
- Make it easier for learners to communicate with one another (e.g. Roschelle & Teasley, 1996; Suthers, 2002, Kozma et al, 2000)
- Are more specific and hence suitable for representing situations where ambiguity undesirable (Stenning & Oberlander, 1994)
- Require epistemological commitments from learners (Kress & Van Leeuwen, 2001)
- Are often reported to be associated with increased motivation and positive affect
- Can support gesturing (e.g. Nathan & Johnson 2010)
- Encourage self-explanation (e.g. Ainsworth & Loizou, 2003)
- But may lead to illusion of knowing (e.g. Salamon, 1994)
Understanding how representations influence learning

Representation

- Aesthetic
- Motivation
- Strategic
- Motor
- Metacognitive
- Social
- Epistemological
- Affect
- Cognitive
- Expressive
- Perceptual
Understanding how representations influence learning

Cognitive

- Perceptual
- Expressive
- Representation
- Aesthetic
- Motivation
- Strategic
- Motor
- Metacognitive
- Social
- Affect
- Epistemological

Ainsworth (2008) in Robinson & Schraw (Eds.)
Inconsistent Results

(Task * Representation * Learner * Assessment * Context)

Scheiter, 2009
Some Implications

- Far too much existing research fails to acknowledge this complexity: findings are conceptualized, researched and interpreted within a single level of explanation (e.g. working memory, affect)
  - We must broaden our theoretical outlooks and adopt methods which allow us to be sensitive to this complexity
- The levels interrelate - changing the way representation to take account of factors at one level will change its properties at another
  - Are some explanatory concepts more powerful than others (in certain contexts)
- In my view, we are too early for ‘proven’ design principles to guide us in the design and choice of visual representations:
  - Picture + Text better than text alone
  - Modality effect? Specificity effect? Affect effect? Non-information equivalence effect?
Support learners to make meaning from multiple representations <your favourite technique here>:
Constructive and Communication

- Children’s Collaborative Story Telling
Study 1

- Study compared 12 triads of children making stories with interactive drawing tool (KidPad) against same triads of children making a different story together with Non-interactive tool (within subjects design)
- Made Story; Tell story to audience; Remake story (condition manipulation) retell story to audience
- Children’s stories improved significantly when they were using interactive KidPad: stories were
  - Longer
  - Better structured
  - More elaborate
- BUT of the collaborative process of story-making revealed that very little talk occurred among collaborators.
Study 2: Scripted Collaboration

- Study compared 18 pairs of children making stories with interactive KidPAd both with and without GRQ script (within subjects design)
- Made Story; Tell story to audience

<table>
<thead>
<tr>
<th>Question</th>
<th>Why?</th>
</tr>
</thead>
<tbody>
<tr>
<td>What have you <strong>drawn</strong>?</td>
<td></td>
</tr>
<tr>
<td>What does [the character] <strong>look like</strong>?</td>
<td></td>
</tr>
<tr>
<td>How is [the character] <strong>feeling</strong>?</td>
<td></td>
</tr>
<tr>
<td>What is [the character] <strong>thinking</strong>?</td>
<td></td>
</tr>
<tr>
<td>What does [the character] <strong>want</strong>?</td>
<td></td>
</tr>
<tr>
<td>Where is this <strong>taking place</strong>?</td>
<td></td>
</tr>
</tbody>
</table>

Gelmini, Ainsworth & O’Malley (in press) Int. J
Results – Story-making

- Median No of Questions Asked

<table>
<thead>
<tr>
<th>No Prompts</th>
<th>Prompts Second</th>
<th>Prompts First</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>5</td>
<td>10</td>
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<td>10</td>
<td>15</td>
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<td>20</td>
<td>25</td>
<td>30</td>
</tr>
<tr>
<td>30</td>
<td>35</td>
<td>40</td>
</tr>
</tbody>
</table>

Graph showing the comparison between No Prompts and Prompts for the median number of questions asked.
Results – Story-telling

Coherence (% turns)

Evaluative Richness (no of propositions)

[Graphs showing the comparison between No Prompts and Prompts for Coherence and Evaluative Richness]
Representations should be fun

- **Intrinsic Integration:**
  - Deliver learning material through the parts of the game that are the most fun to play, riding on the back of the flow experience produced by the game, and not interrupting or diminishing its impact. [fun]
  - Embody the learning material within the structure of the gaming world and the player’s interactions with it, providing an external representation of the learning content that is explored through the core mechanics of the game. [rules]

Habgood, Ainsworth & Benford (2005) *Simulation and Gaming*
Defeating enemies labelled with numbers by attacking them with a weapon that divides their number into whole parts.

Panel represents controls and divisors.

Supported by a multiplication table.

Choice of three attacks on each level.
Defeating enemies labelled with symbols by attacking them with those weapons.

Panel represents attack controls only.
Study 1: Procedure

- Fifty-nine, 7 and 8 year olds (29m 30f)
- Total game play 2 hours 15 minutes
- Teacher led reflection: whole class by condition
- Tests delivered on computers in symbolic form (closest to extrinsic condition)
Study 1: Learning outcomes

[Graph showing results for Intrinsic, Extrinsic, and Control conditions over Pre, Post, and Delayed periods.]
Study 2: Motivation

Version Switching
- Sixteen 9-11 year olds attending a regular after school club (11m 5f).
- Free switching between versions or their usual club pursuits.
- Recorded time playing ZD over 2½ hours of potential play.

Time on ZD
- Children spent significantly longer\(^1\) playing the intrinsic (61%) than extrinsic (8%).
- Girls spent statistically longer\(^2\) playing intrinsic than boys (84% vs. 50%).

Interview Data
- “it’s better to learn doing it by intrinsic, because it’s quicker” (intrinsic)
- “more fun because it’s like subliminal advertising with maths.” (intrinsic)
- “you think: oh I’ve had the fun part, now I have to do a test – I’m just going to turn it off and not bother.” (extrinsic)
Learning is enhanced by metacognitive strategies

- A self-explanation - “a piece of knowledge generated by the student that states something beyond what the information gives” Chi et al (1989)
- How does self-explanation differ when you study diagrams or text?
- Is self-explanation more beneficial for learning from pictures or text?
  - Cox (1999) proposes that diagrams will facilitate the self explanation effect.
  - Wilkins (1997) argues that diagrams inhibit the self explanation effect.
Method: Design and Materials

- 10 male and 10 female (19 to 23 yrs) participants learnt about the cardio-vascular system through either text or diagrams
- Pre-tests, training, learning, post-test (pre-tests + more)

**Blood Vessels**

The large, muscular vessels that carry blood away from the heart are called arteries. Blood travels through a network of smaller arteries, which in turn divide and form even smaller vessels called arterioles. The arterioles branch into a fan of tiny vessels called capillaries. De-oxygenated blood flows through capillaries that merge and form larger vessels called venules. Several venules in turn unite to form a vein, a large blood vessel that carries blood to the heart.
Results

- Students given pictures learnt more
- And gave significantly more self-explanation
- Text students spent longer studying and they spoke more (i.e. paraphrased)
Self-explanation need not only be verbal

- Human life depends on the distribution of oxygen, hormones, and nutrients to the cells in all parts of the body.

- At the lungs the pulmonary artery divides into two smaller arteries, one leading to each lung.
- Oxygenated-blood then flows into venules, which merge into the pulmonary veins that lead to the left atrium of the heart.
- Blood from the left ventricle enters systemic circulation through the aorta.

Ainsworth & Iacovides (2005) EARLI
Drawing to Learn (in Science)

- Drawing to enhance engagement:
  - when students draw to explain they are more motivated to learn compared to traditional teaching of science

- Drawing to learn to represent in science
  - the process of producing visual representations helps learners understand how scientific representations work

- Drawing to reason in science
  - student learn to reason like scientists as they select specific features to focus on in their drawings, aligning it with observation, measurement and/or emerging ideas

- Drawing to communicate
  - discussing their drawings with their students provides teachers with windows into students’ thinking as well being a way that the peers can share knowledge, discovery and understanding

- Drawing as a learning strategy ....

Ainsworth, Prain & Tytler (2011) Science (this week!)
Learning by drawing from written text is multimodal, effortful, interactive, often fun, supports communication (and is supported by dialogue)

“Valves prevent the blood from moving backward or downward. These valves allow blood to flow in only one direction through the veins.”
Drawing can learners make their ideas explicit

- So they can overcome limitations in presented material
- Organize and integrate their knowledge
- Ultimately can be transform their understanding
- Studies (e.g. Gobert & Clements, 1999; Van Meter et al 2001, 2006) typically ask learners to draw after reading compared to either reading alone, writing summaries, seeing pictures + text)
- Drawing (particularly when supported) is effective especially on tests of deeper knowledge
Changing the audience of drawing

- How does learning by drawing differ when you draw for others or yourself?
- Compared learners who drew an explanation
  - for themselves “draw a diagram that helps you understand”
  - for a peer to learn from (described as having the same level of knowledge)
- Can you predict learning outcomes from analysis of drawings?
- How should you analyse drawings?
Peer diagrams contain more content, words, are judged as clearer.

No more effective at improving understanding

Ainsworth et al (2007) EARLI
So where are we now..

- Research should do more to understand how to design representations:
  - when and for whom particular (combinations of) representations will be beneficial
- AND how to use them effectively
  - Uncover how best to support learners to make meaning from multiple representations
Effective representation help learning...

- **Through interpretation:**
  - Well-designed representations manipulate information to make its key aspects (task relevant) more accessible to the learner for beneficial cognitive, social and affective processes.

- **Through construction:**
  - Learner generate or invent useful representations that express their current understanding and provide a basis for going beyond this knowledge in ways that involve beneficial cognitive, social and affective processes.

Ainsworth & Lowe (in press)
Encyclopedia of the learning sciences
Effective Multiple Representations help learning

- If combinations of representations are used wisely
  - taking into account their costs and benefits
  - and what your learners already know
  - and if they are designed to achieved a particular function
Strategies

Individual Differences

Tasks

Dr. Ainsworth (1999) Computers & Ed
Constraining Interpretation

Right Side

<table>
<thead>
<tr>
<th>Atrium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Septum</td>
</tr>
<tr>
<td>Ventricle</td>
</tr>
</tbody>
</table>

Deoxygenated

Oxygenated

Left Side

Right Side
Support learners to make meaning from multiple representations

- <your favourite technique here>: 
- encourage sustained effortful (though playful) constructive activity, supported through communication, interaction, and reflection
Where next (for me and maybe for you?)
Longer studies....

- Are we actually researching learning with representations or learning representations
  - Studies typically present materials for a few minutes and with limited training
- And studies of more expert use of representations
  - E.g. Kozma; Latour, Goodwin, Gooding
Changes over time

- **Dynamic**
  - All reps looked at, some very briefly
  - Too many for learners to focus on them

- **Static**
  - Selective, fewer and open for longer periods
  - Less interaction

Ainsworth (will write up someday honestly I promise)
Understanding the teachers roles in multi-representational learning

- E.g. Tytler, Prain, Hubber, Waldrop (RILS)
- E.g. Sandra Nitz

![Diagram showing the roles of learners and teachers in multi-representational learning](Image courtesy of David Blackwell)
We need to match the form of the assessment to the nature of the task and the learning (Lowe, Rasch, & Schnotz, 2011)

Maybe we should be assessing representational and (meta) representational competence

When learners can understand, select, explain, critique and even invent relevant representations
Raising our Game...

- Process and Outcome becomes the norm not the exception
  - Cognitive accounts are great at outcome but too often no (or little) analysis of process and no relation between the two
  - Social Semiotic and Socio-cultural accounts are great at process but often have no (or little) no analysis of outcome and no relation between the two

- Replication Studies
- Studies aimed at falsification and/or identifying fundamental mechanism
And mostly by joining us
Thanks to my collaborators

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