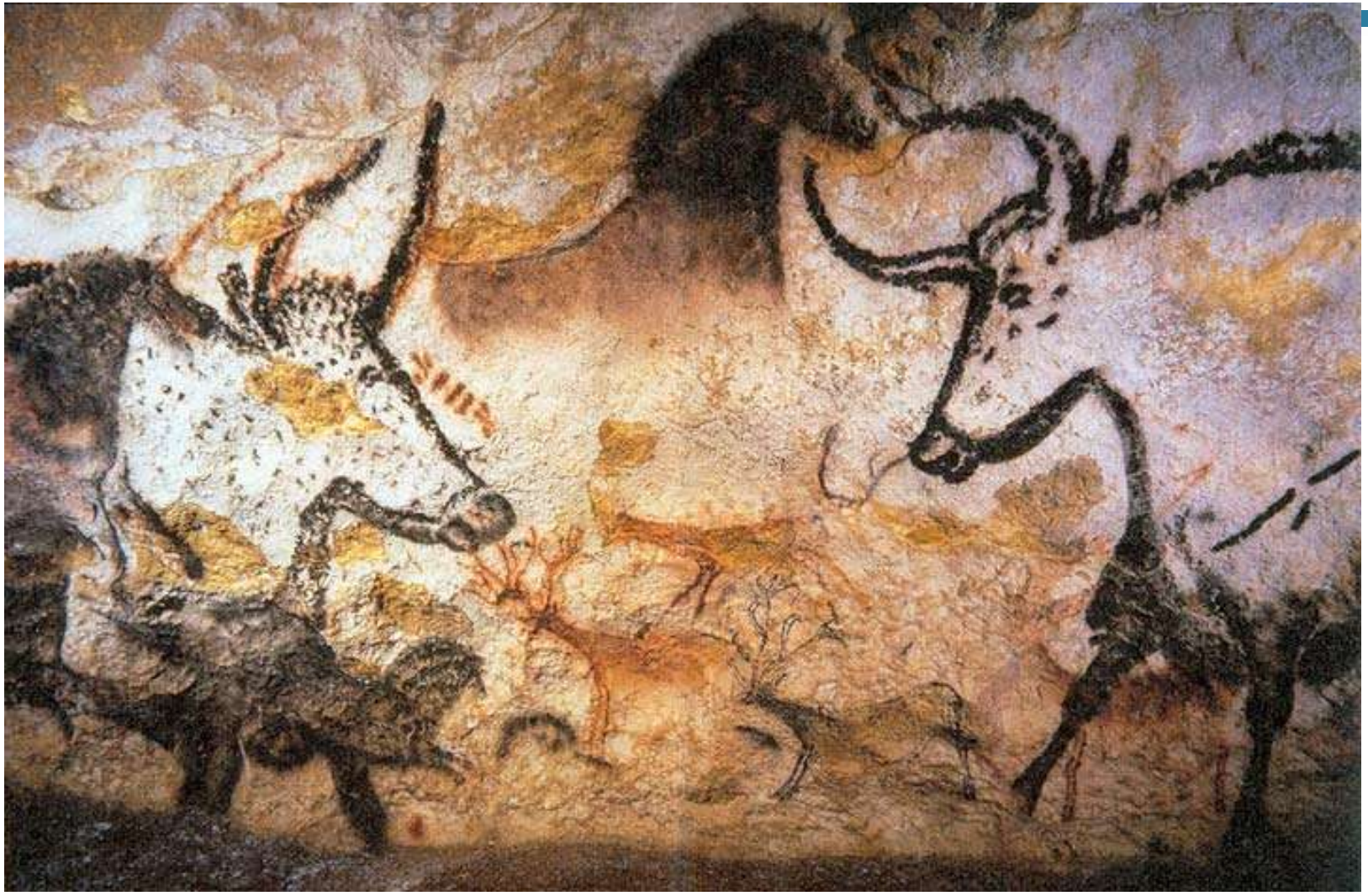
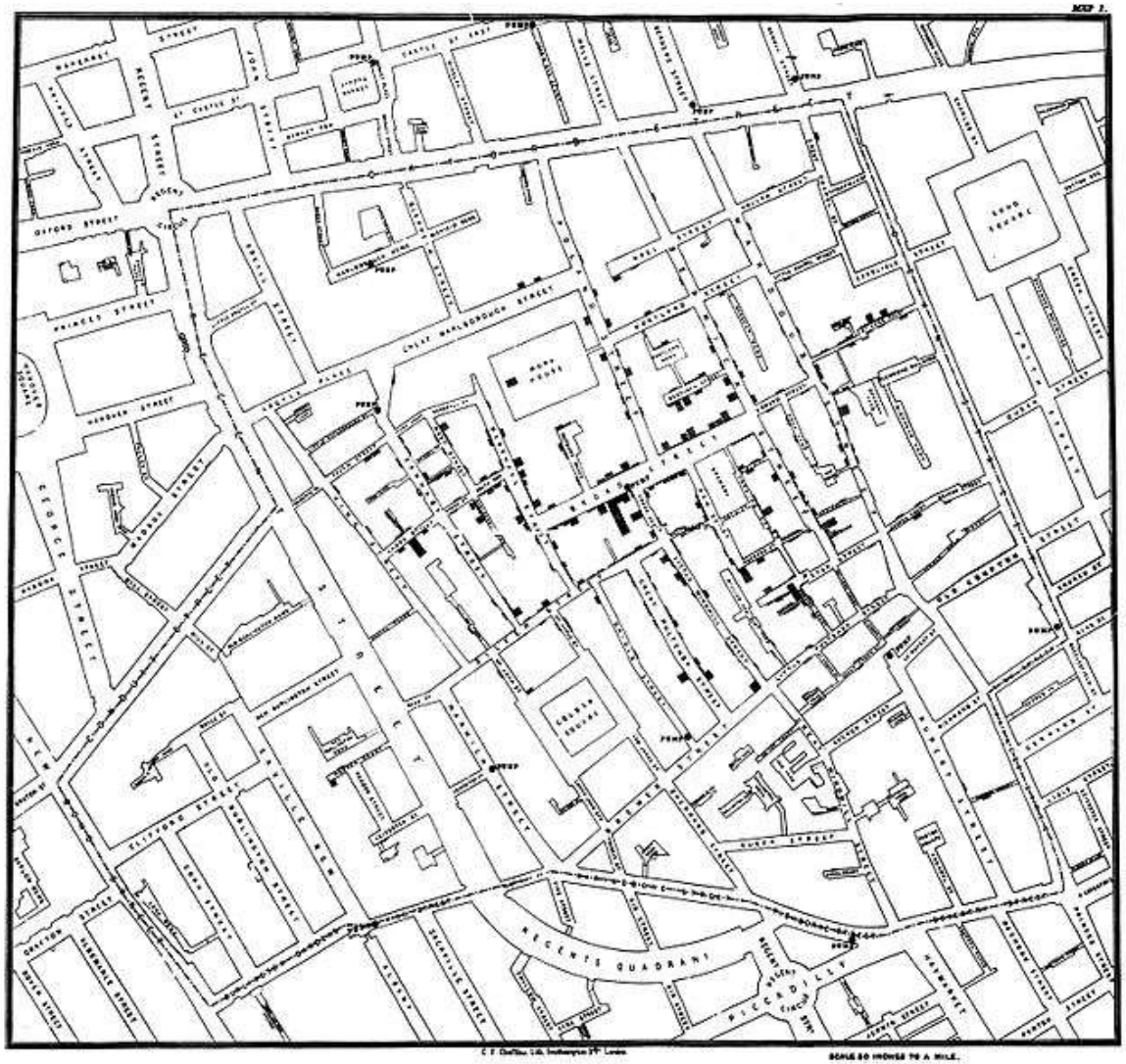
WHAT (AND WHY) CAN WE LEARN BY DRAWING?

SHAARON AINSWORTH

AUROCHS AT LASCAUX CIRCA 15300 BC



1854 BROAD STREET CHOLERA OUTBREAK



NAPOLEON'S MARCH: CHARLES MINARD 1869

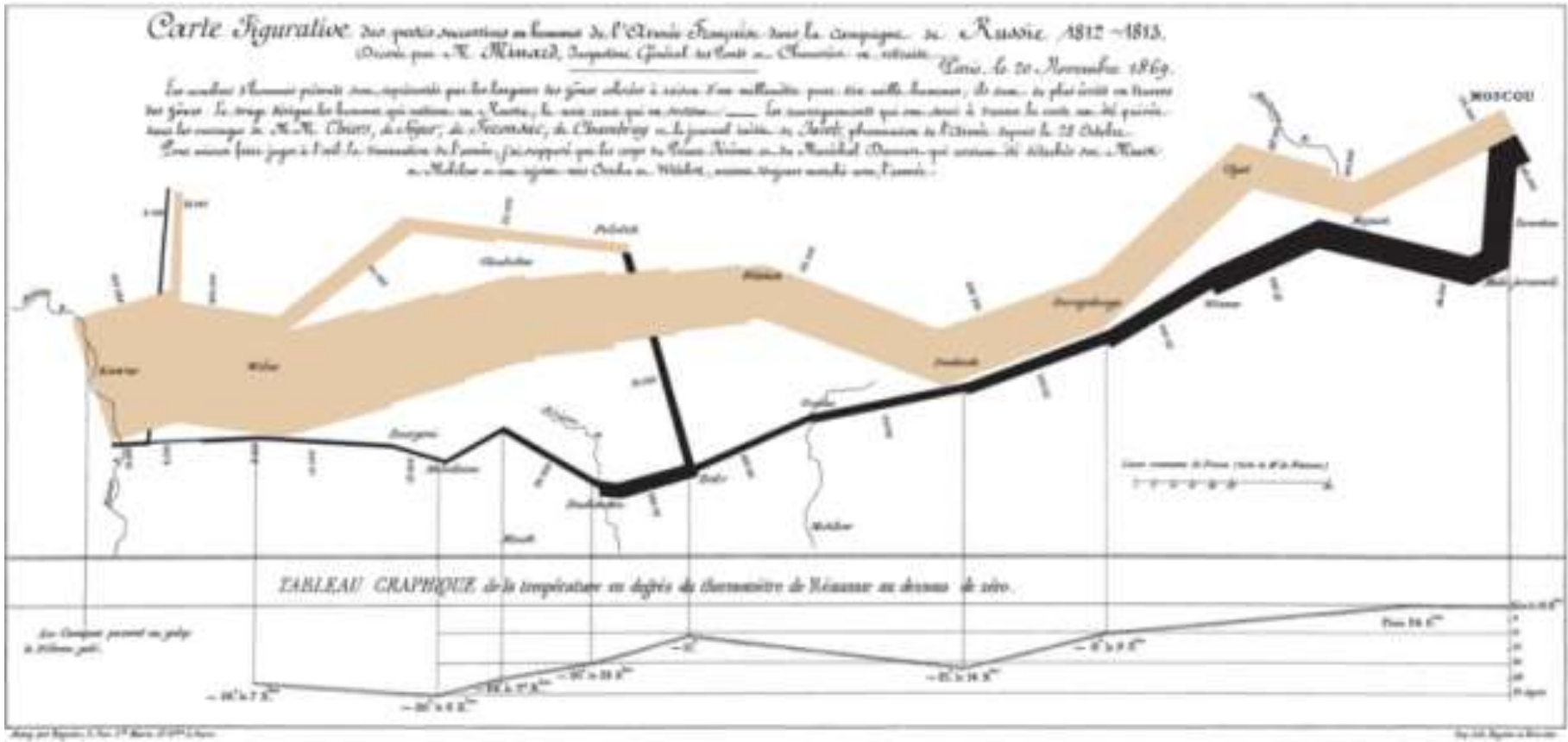
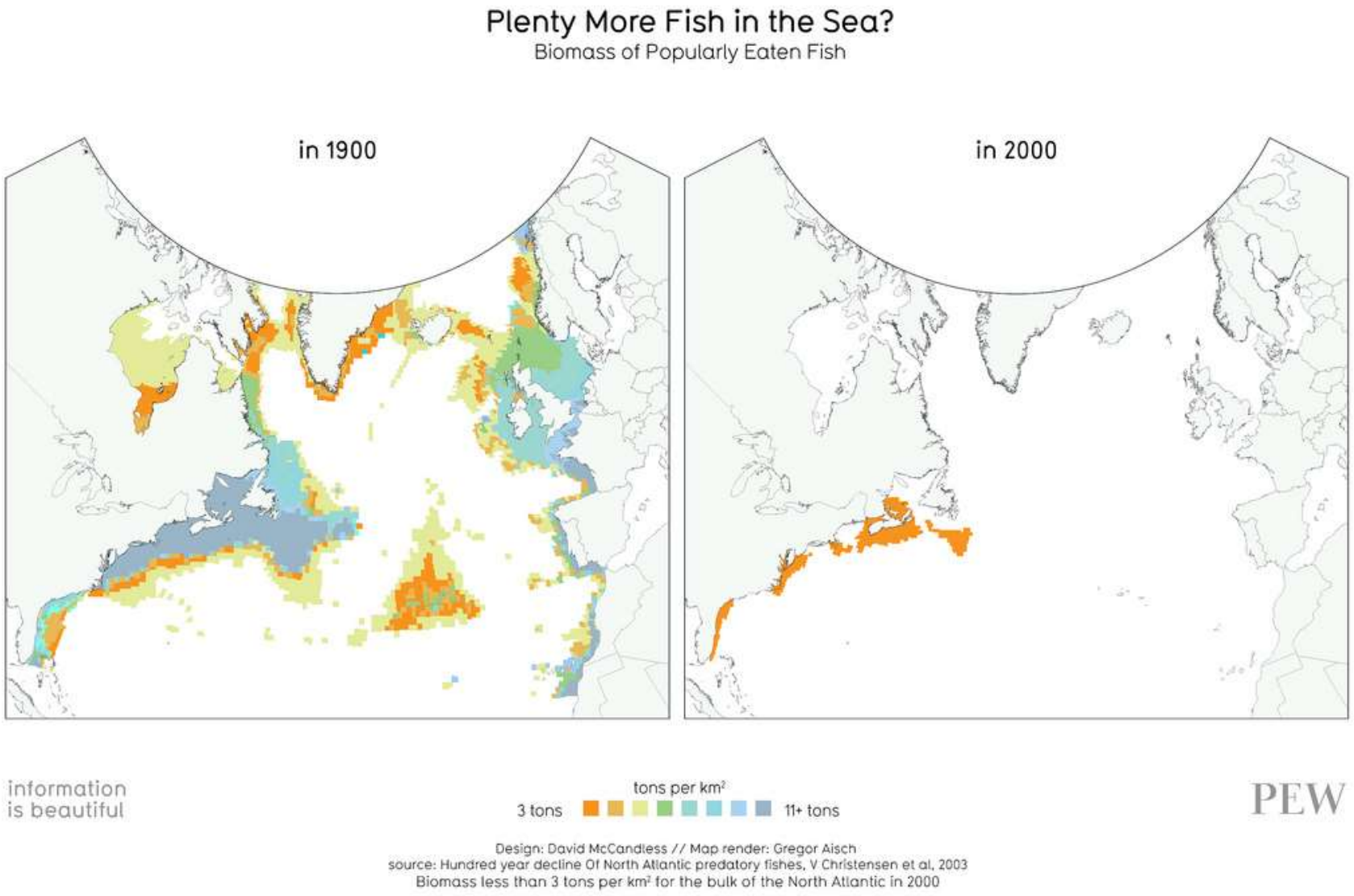
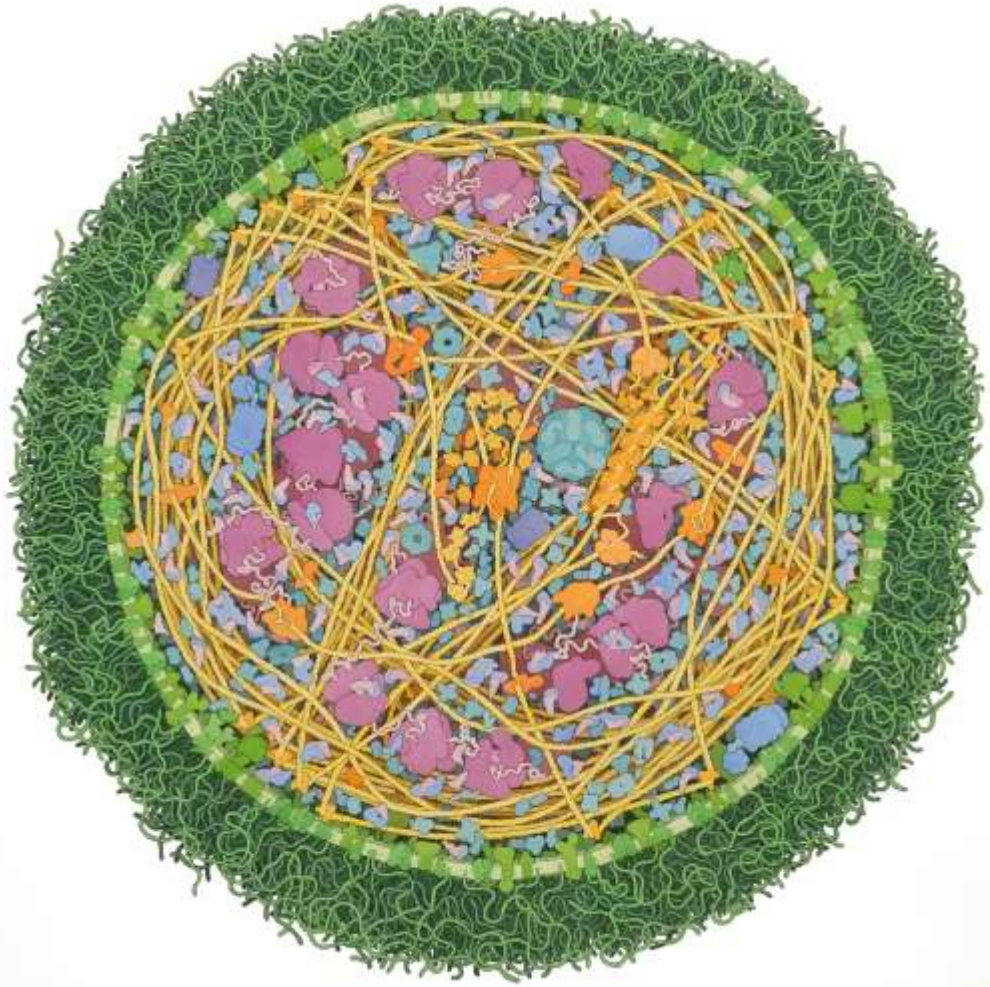


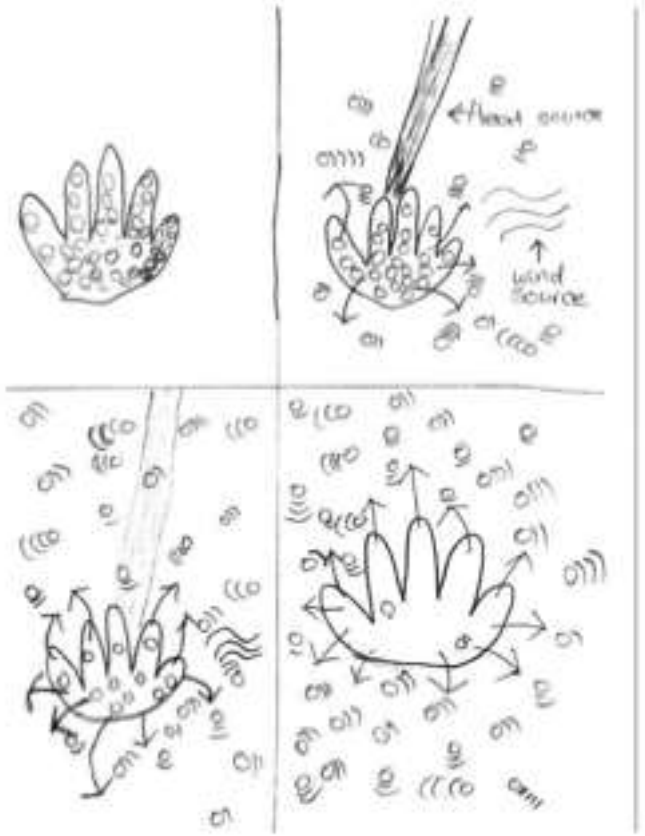
IMAGE COURTESY OF DAVID MCCANDLESS INFORMATION IS BEAUTIFUL

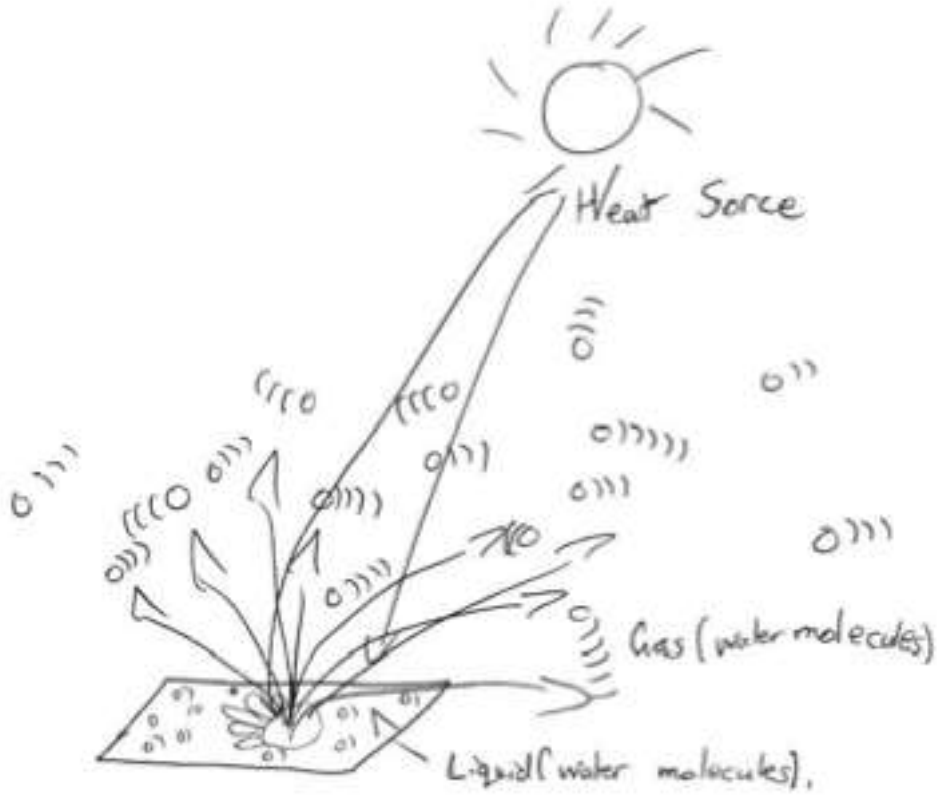


MYCOPLASMA MYCOIDES CELL
DAVID S. GOODSELL



CHILDREN DRAWING AN EVAPORATING HAND PRINT





OUTLINE

- What do I mean by drawing?
- What roles can drawing play
- Why should we encourage drawing in formal and informal education?
- What next….

MY DEFINITION OF DRAWING

- Learner-generated drawing involves learners constructing graphical representations to achieve a learning goal.

FOUR ELEMENTS AND CAVEATS

- The focus is on **learners** not on people drawing to teach
- **Construct** as opposed to (solely) interpret
  - I include computer drawing as well free hand but I exclude "selection from a palette"; some don't
- **Graphical** representations as opposed to textual
  - I see this more as a continuum not categorical distinction
  - I would not see spatially organized text as a drawing (although many learners and some researchers do)
- **Learning goal** as opposed to artistic intent, self-expression, etc

DRAWING TO LEARN (STEM)

- Drawing to enhance engagement
- Drawing to learn to represent in science
- Drawing to reason in science
- **Drawing as a learning strategy**
- **Drawing to communicate**

Ainsworth, Prain & Tytler (2011) **Science**

…TO ENHANCE ENGAGEMENT

- Many students disengage from school science because transmissive teaching, traditional topics, and unchallenging tasks reduce them to passive roles
- When students draw to explain they are more motivated to learn compared to traditional teaching of science (Hackling & Prain, 2005)
    - NB weak evidence for this claim

…..TO REPRESENT IN SCIENCE

- Generating their own representations can deepen students' understanding of the how representations work
- Students understand how to interpret representations better if they also construct them
  - E.g. students understanding of novel line graphs of supply and demand was better if they had previously constructed them rather than just interpreting them (Stern et al , 2003)
- Students understand the specific purposes of a representation
  - E.g. that a line graph is particularly good choice if you need to show continuous quantitative information (Gilbert, 2005)
- And how representations work more generally
  - For example, scientific representation are generally speaking better when they are coherent, compact, and parsimonious (diSessa, 2000)

AND THEY NEED DO

- Because scientists rely on diagrams, graphs, videos, photographs, and other images to make discoveries, explain findings, and excite public
- From the notebooks of Faraday and Maxwell (Gooding, 2003) to current professional practices of chemists (Kozma et al, 2000)
- scientists imagine new relations, test ideas, and elaborate knowledge through graphical representations (Gilbert, 2005, Lemke, 2004, Latour, 1999)

…TO REASON IN SCIENCE

- To show conceptual understanding, students must learn how to reason with multiple, often visual, modes (e.g. Duschl & Grandy, 2005)
- For example, what are the properties of water?
  - Its attraction to polar molecules.
  - High-specific heat.
  - High heat of vaporization.
  - The lower density of ice.
  - High polarity

BUT THIS IS HOW A CHEMIST MIGHT DO IT

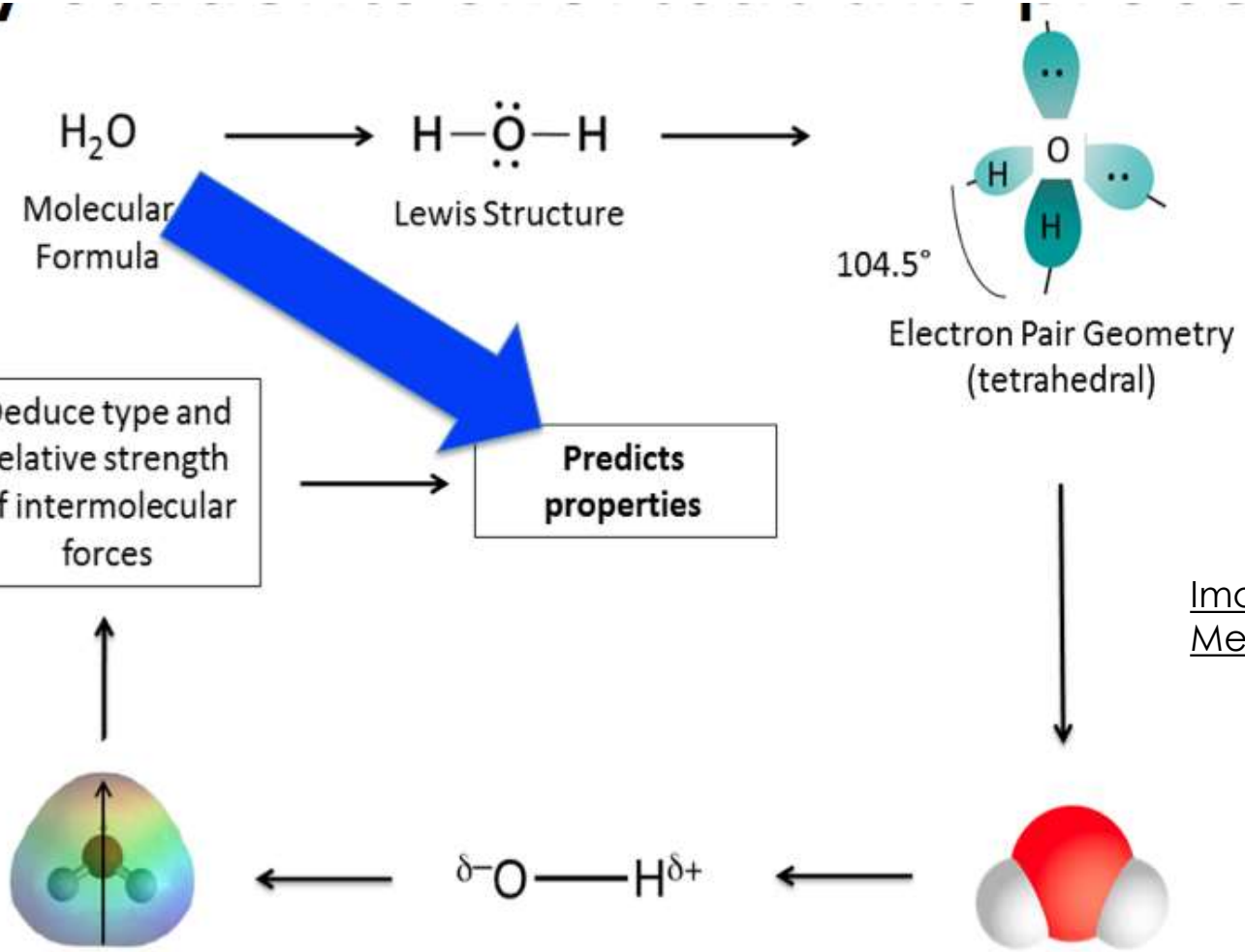


Image courtesy of Melanie Cooper

… AS A LEARNING STRATEGY

- It is a constructive process that helps learners make their ideas explicit enabling them to overcome gaps in material or generate new inferences, in a way that is analogous to the self explanation effect
- As this new knowledge is then expressed as an external visualization, it can leverage complementary perceptual and memory benefits to, in turn, prompt new understanding (Ainsworth and Nathan, 2012)

MY CURRENT DRAWING STRATEGY STUDIES

- What does learning by drawing depend on and can we improve it. For example:
  - Does it matter who you draw it for?
  - Does it matter if you are good at drawing?
  - Can drawing to learn be trained and if so what should be trained?
  - Are there specific benefits for drawing or is it similar to other constructive strategies
- *Drawing after self explanation training (with Jo!); Drawing from presented images v text; Drawing on paper v on tablets, drawing after someone draws in front of you, drawing when from material versus drawing from memroy*

TYPICAL PLAN OF STUDY

- Domain: Cardio-vascular system, respiratory system, water cycle, greenhouse effect
- Ages: 10 to undergraduate
- About 50:50 lab and real world
- Procedure
  - (some of) Drawing Abilities, Learning Habits, Spatial skills, prior knowledge
  - Pre-test (e.g. MCQs, diagrams, definitions)
  - **Intervention (read 5-15 sections of texts, and draw**)
  - Post-test (MCQs, diagrams, definitions, 'deeper questions', transfer)

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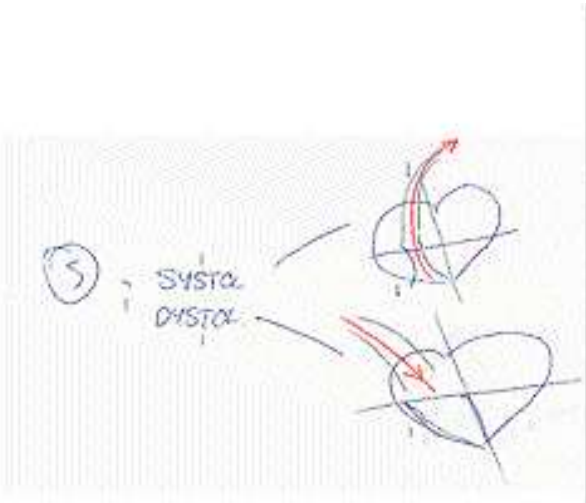
DRAWING FOR SELF OR OTHERS:

- Lab study with 40 UG students studying cardio-vascular system
- 20 asked to draw the diagrams to aid their own learning,
- 20 were asked to draw diagrams to aid the learning of another person. The 'recipient' of the diagram was described as having not studied biology past the age of
- They drew based upon 13 passages of texts containing information about the human circulatory system. No time limit was enforced.

Ainsworth, Musgrove and Galpin (as yet unpublished)

SELF…… OTHER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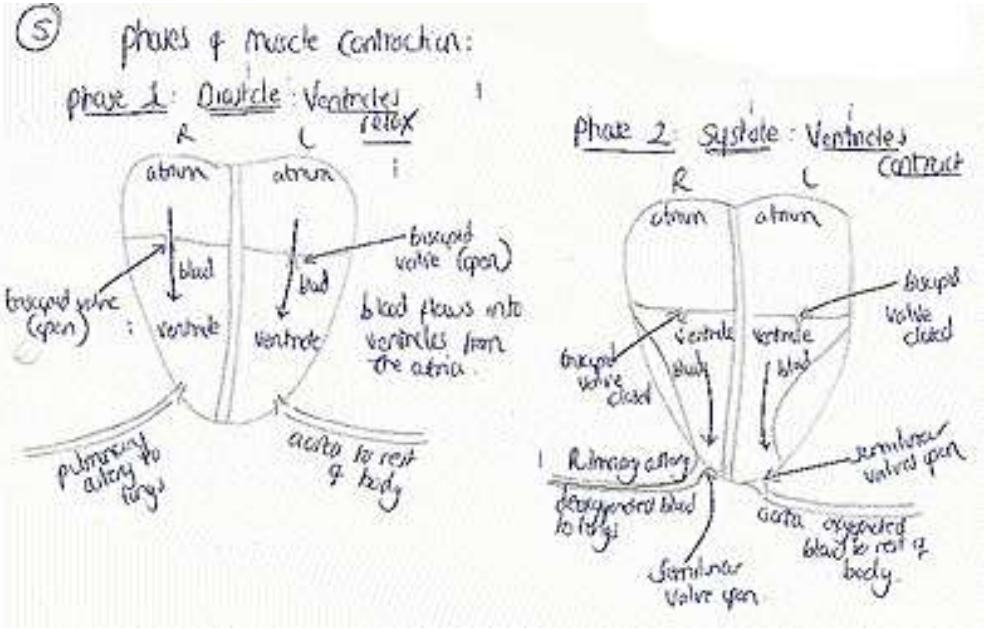
5
phases of muscle contraction:
phase 1: Diastole: Ventricles relax
R
L
atrium
atrium
bicuspid valve (open)
blood
blood
bicuspid valve (open)
ventricle
ventricle
blood flows into ventricles from the atria
pulmonary artery to lungs
aorta to rest of body
Phase 2: Systole: Ventricles Contract
R
L
atrium
atrium
bicuspid valve closed
ventricle
ventricle
bicuspid valve closed
blood
blood
Pulmonary artery
deoxygenated blood to lungs
semilunar valves open
aorta
oxygenated blood to rest of body
Semilunar valve open

DRAWING FOR SELF OR OTHERS

- Everyone learnt (a lot) but no differences in learning outcomes
- Diagrams were judged as (significantly) clearer, contained more information and used more words if drawn for others
- Took much longer to create
- No difference in how abstractly they were drawn
- Drawings which were richer in content were associated with better learning outcomes
- Drawings which were more concrete were associated with better learning outcomes but this was completely explained by prior knowledge

MY CURRENT DRAWING STRATEGY STUDIES

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  - Are there specific benefits for drawing or is it similar to other constructive strategies

TRAINING AND DRAWING SKILLS

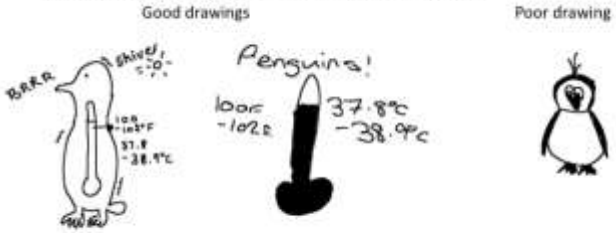
- Lab study with 64 UG students studying respiratory system
- Bender Visual-Motor Gestalt Test was used as a measure of drawing ability
- Half interacted with the researcher for a while…
- Half participants were trained by studying a presentation that described features of 'good' drawings, showed examples (on a unrelated topics) and practiced the strategy receiving feedback. The emphasis was on content, explicitness and completeness rather than on aesthetics.

Ask yourself these questions

- Have I thought about all the possible meanings in the text?
- Is all the information from the text present in the diagrams?
- Have I included relevant prior knowledge to aid my understanding?

An Example: how penguins are adapted to the environment.

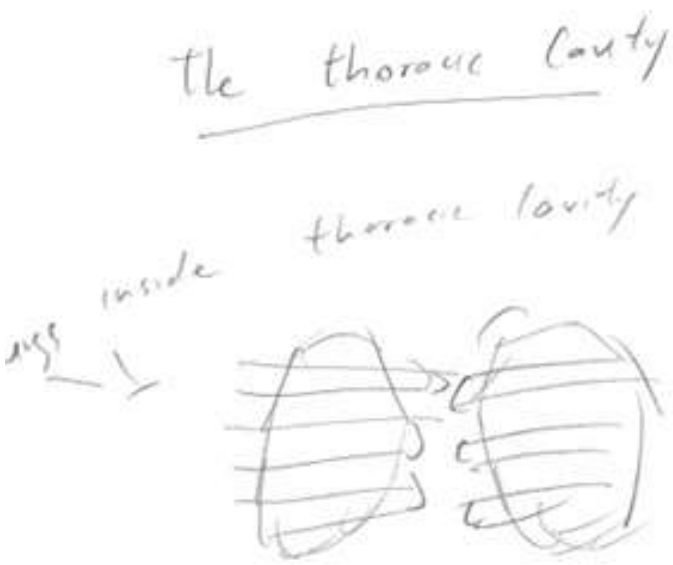
The internal temperature range of penguins is 37.8ºC to 38.9ºC (100ºF-102ºF). They also may shiver to generate additional heat.



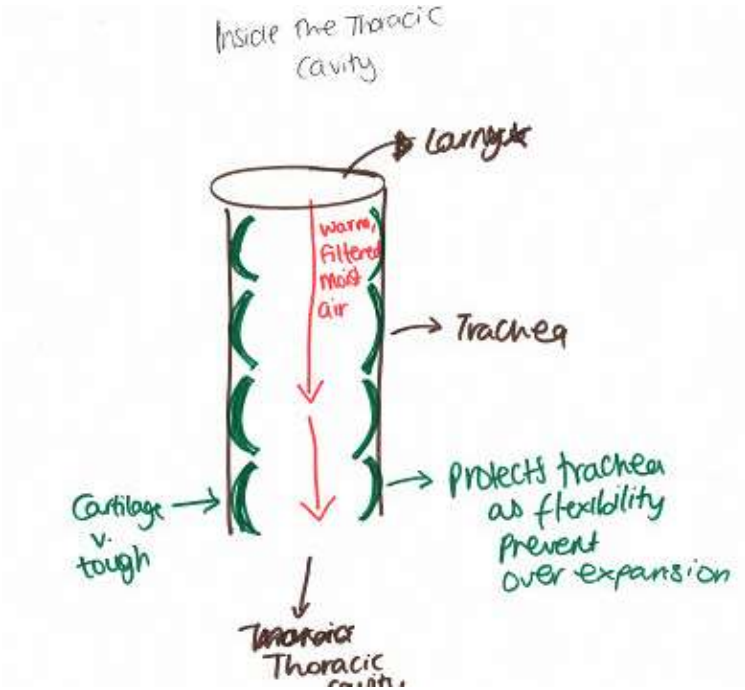
Please discuss with the experimenter what makes these good or poor drawings.

DRAWINGS

Non trained



Trained



The trained group produced diagrams that were significantly clearer and richer in content.
Drawing abilities was significantly associated with all measures (clarity, content and abstraction)

SUMMARY

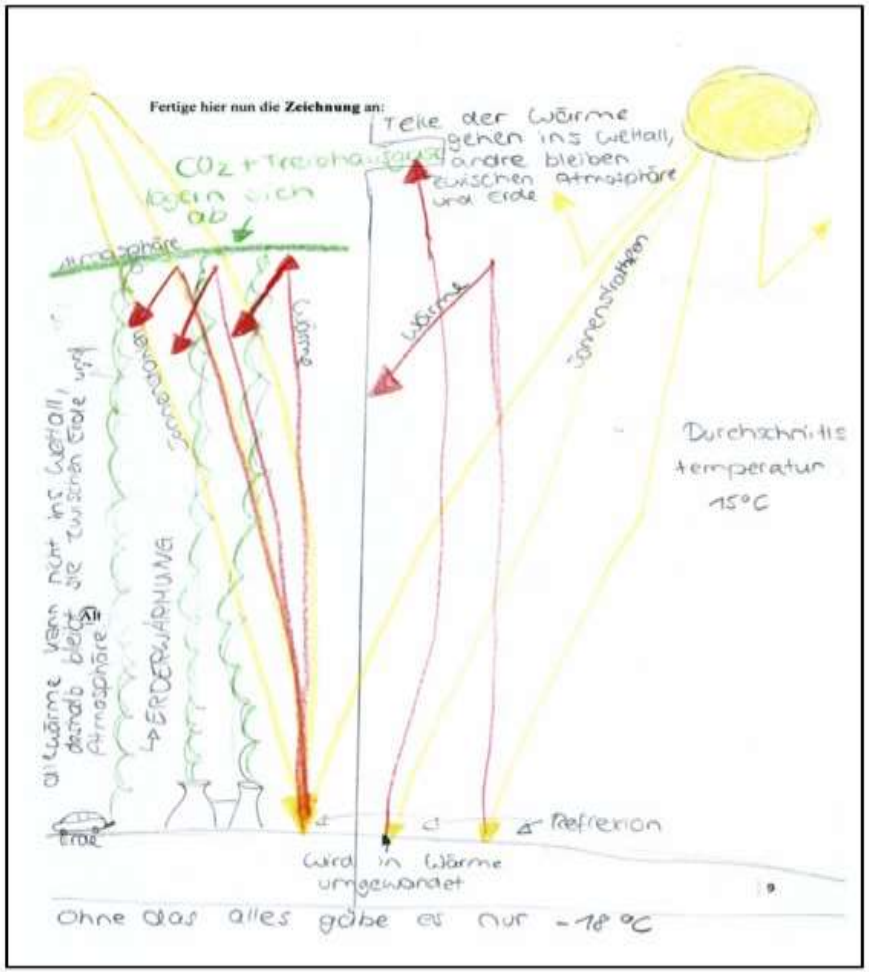
- The effectiveness of drawing as a learning strategy did not depend upon drawing skills
- The effectiveness of drawing as a learning strategy was not enhanced by training in terms of outcomes
- But drawings themselves were influenced by both training and BG scores.
  - So training worked to some extent but maybe not enough (9% difference in content)
  - Maybe only some questions need "content" rich drawings
  - Limitation: deep post-test scored average 20% ☹

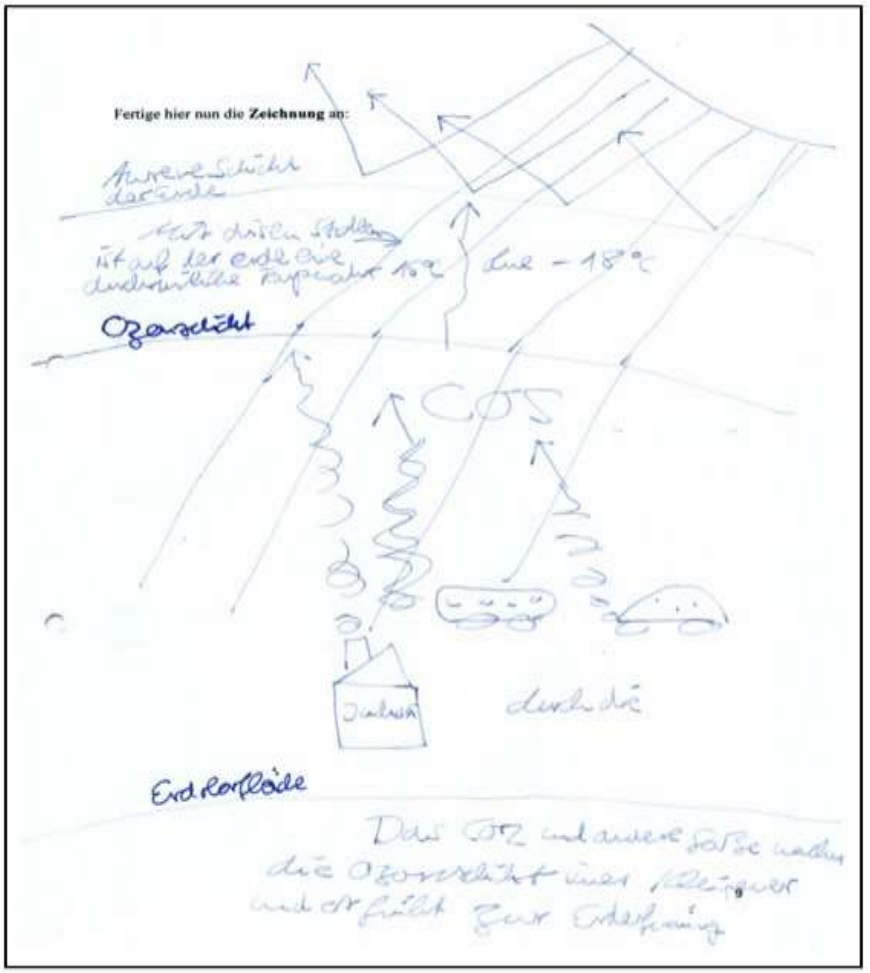
DOES DRAWING HAVE A SPECIFIC EFFECT

- 73 12-13 years old; school study; a single 150 word text on the green house effect
- Test of scientific literacy (pre)
- Half trained to self-explain and half to draw using a text about the water cycle

Scheiter, Schelinshock and Ainsworth (2017)

DRAWINGS: CATEGORIZED AS HIGH AND LOW QUALITY



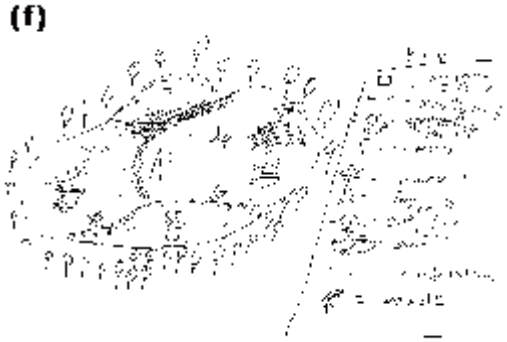


RESULTS

- Drawing slightly better than self explaining at definitional questions but equal on transfer performance.
- However, those who drew high quality drawings learnt more than those who did low quality drawings or self explained.
- Drawing does seem to have specific effects that are different to self explaining but only if the students can master its demands.

TO COMMUNICATE (WITH PEERS)

- Through drawing, students make their thinking visible, leading to opportunities to exchange and clarify meanings between peers.
- The drawings that peers create often are more abstract than those created individually



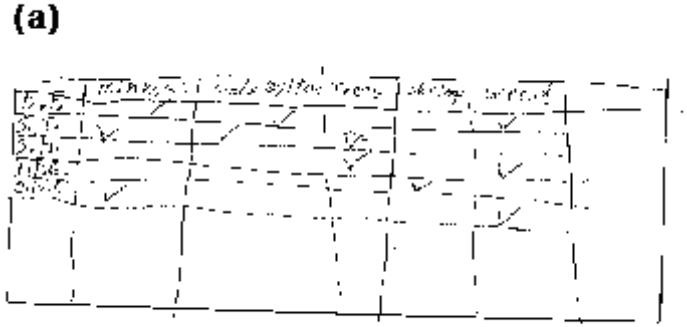


Image courtesy of Daniel Schwartz

TO COMMUNICATE WIT TEACHERS

- AKA assessment!
- Can drawings reveal students understanding more effectively than others methods?

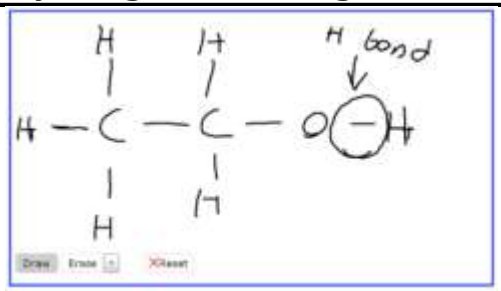
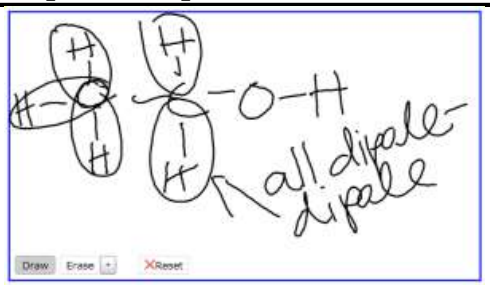
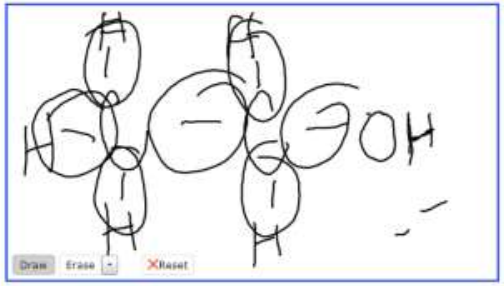
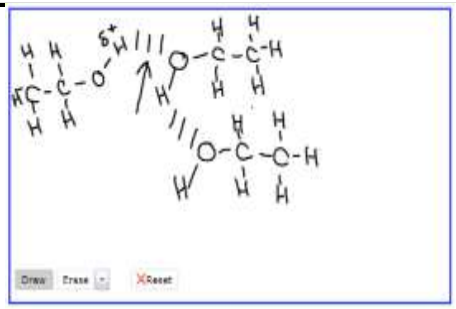
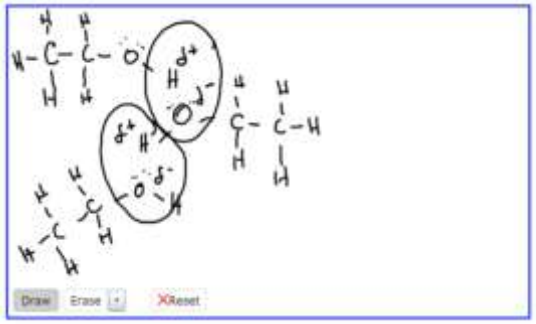
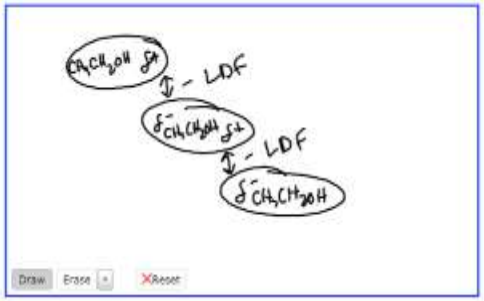
Hydrogen Bonding	Dipole-Dipole	London Dispersion Forces
		
		

Image courtesy of Melanie Coppe

SOME BIG QUESTIONS…

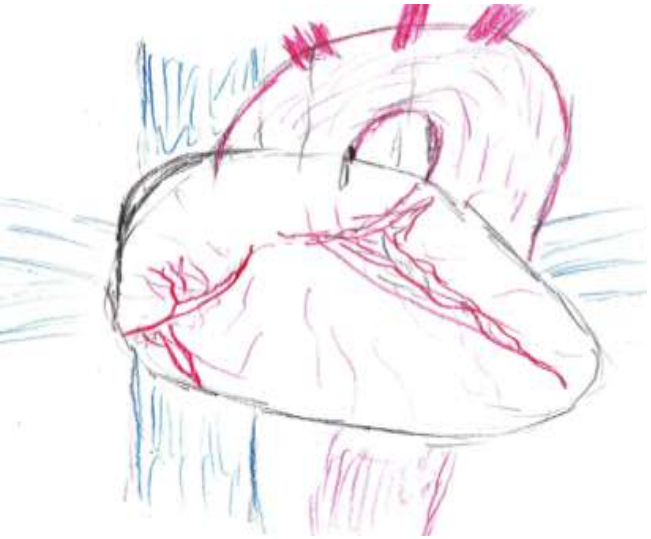
- How should we assess/code drawings ?
  - There is little consensus of what to code and how to code
  - Perhaps publishing our rubrics explicitly and in detail could be a core agenda of our subfield
- Is drawing effective in the real world outside of ”interventions”
- Why does drawing do what drawing does?

TO ASSESS ANATOMY EDUCATION

- Explores students drawing of the heart pre and post dissection of the thoracic cavity
- Real world "natural experiment" conducted in the 2nd week of classes
  - Students attend lecture and study
  - Divided into 4 tasking rooms for pre-dissection briefing
  - 44 of students immediately proceeded for 1 hr of dissection in small groups (5-6) other 54 participants remained in tasking room to study before swapping
  - Both groups were asked during the tasking room study to "draw the external features of the heart to show its anatomical features" in 10 minutes or less
- 46 surgery placement student drew with the same instructions

Panagiotopoulos and Ainsworth (2016)

DRAWINGS



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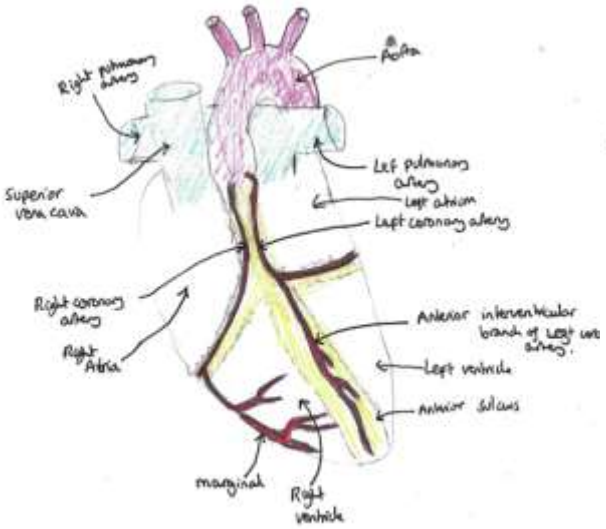

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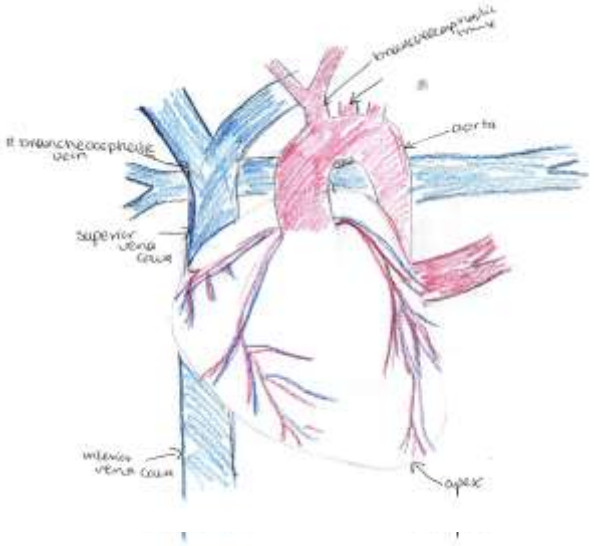


C

CODING….

- How many anatomical features /28 are included ? e.g. superior vena cava
  - Is the shape of it accurate; Is it accurately located; Is the label correct?
- Coding of shape
  - Point of Max Height (l-r); Depth of Max Length (top to bottom); Overall ratio
- Coding of representational features
  - dimensionality; clarity and use of colour

RESULTS

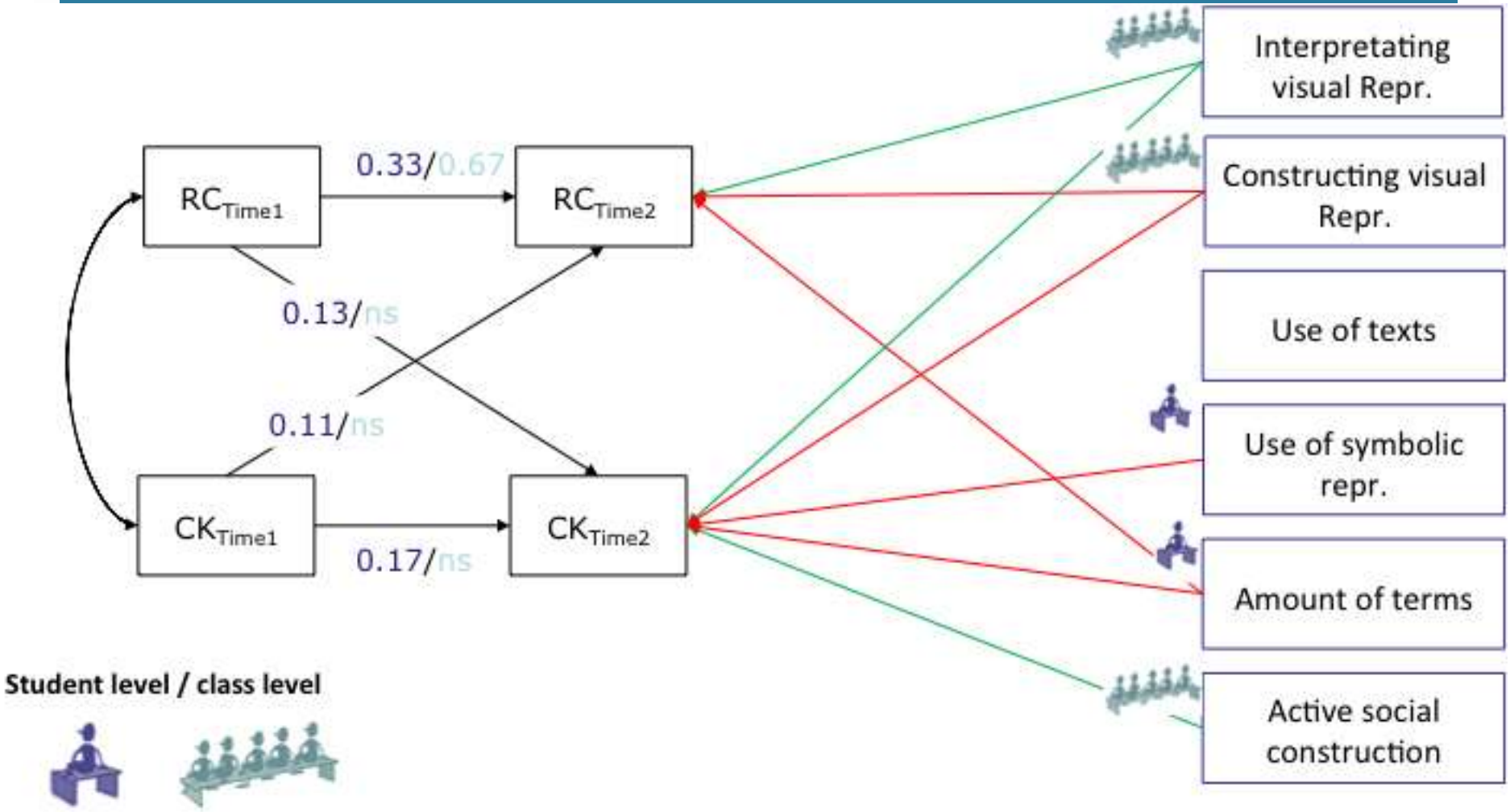
- Third years drawings demonstrated a significantly better understanding of the overall shape of the heart but this had come at the expense of specific content knowledge
- Dissection did not improve 1st years drawings – if anything it seemed to destabilize their understanding but not replace it with anything more accurate
- Lecturers analyzed 1st year drawings:
  - Overall disappointed and surprised at students drawing: fundamental misunderstanding of shapes which they had expected dissection to improve.
- Drawing for assessment?
  - Excellent for overall structures, time consuming and not specially helpful for specific content

DRAWING IN THE REAL WORLD

- Gathered reports on teacher practice and tests from 806 students in 45 classes German Biology classes.
- Multiple choices tests of representational competence (translation across representations) and content knowledge (definitions)
- Instruments which asked students to rate the amount of time spent on specific representational activities

Nitz, Ainsworth, Nerdel & Prechtl (2014)

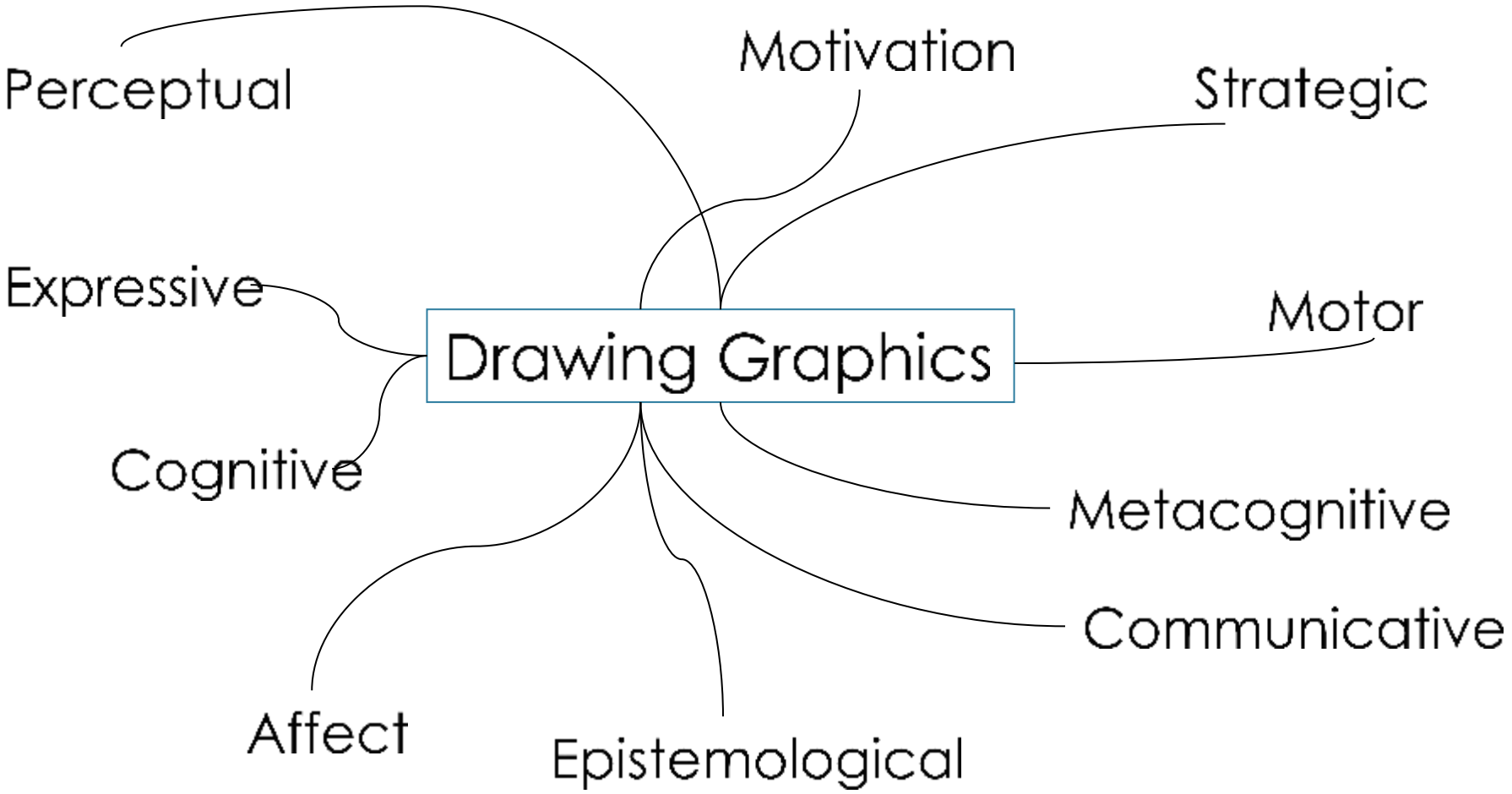
RESULTS


RC Time1
0.33/0.67
RC Time2
0.13/ns
0.11/ns
CK Time1
0.17/ns
CK Time2
Interpretating visual Repr.
Constructing visual Repr.
Use of texts
Use of symbolic repr.
Amount of terms
Active social construction
Student level / class level

WHEN IS DRAWING NOT HELPFUL

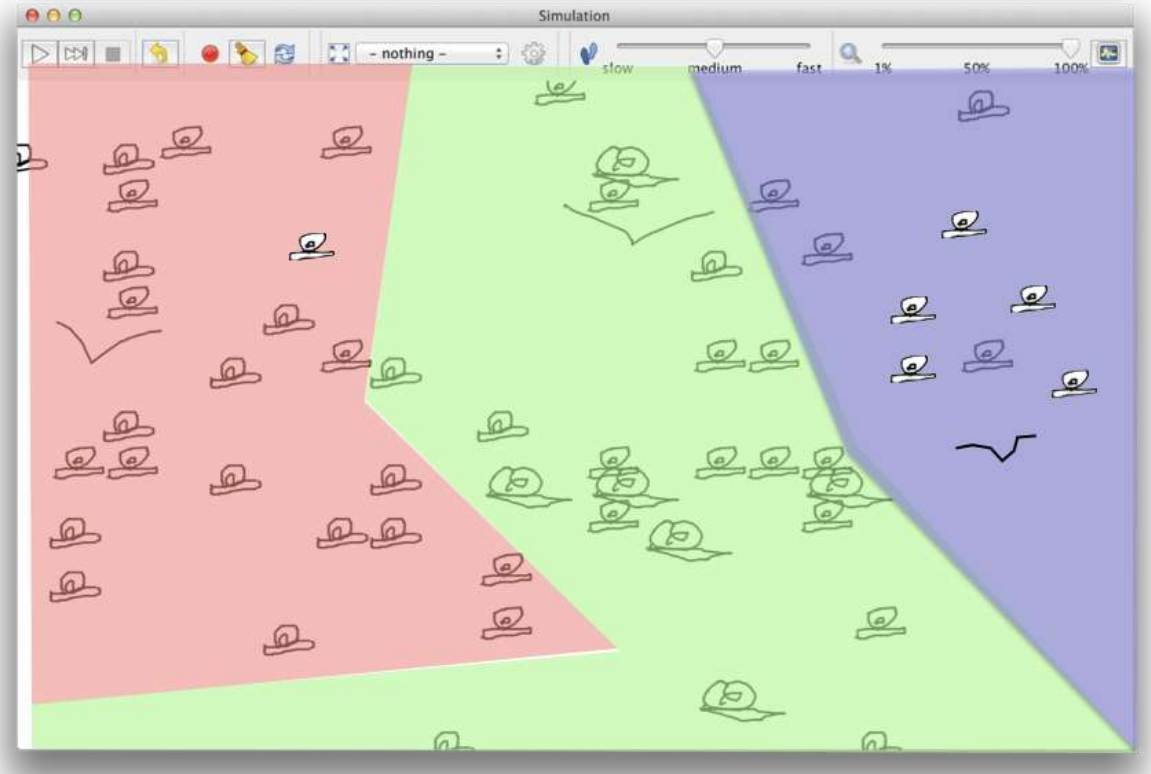
- When drawing becomes merely copying and not an active constructive processes
- When it forces attention to the wrong aspect of a learning situation
- When its make students inappropriately reduce a 3d or 4d situation to 2d
- When its not scaffolded
- If you draw a "bad drawing" could it reinforce your misunderstanding it you don't get prompted to re-inspect it

WHY IS DRAWING TO LEARN EFFECTIVE? I THINK ….



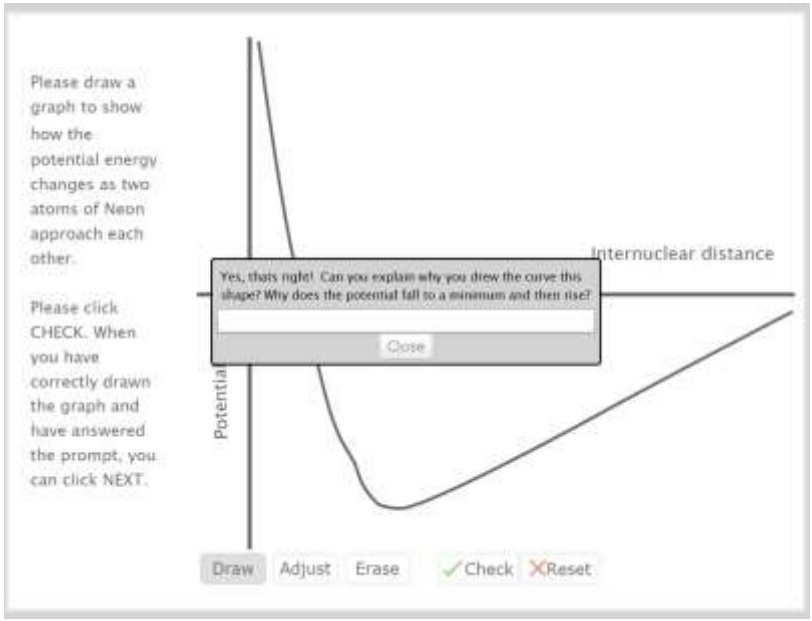
SOME FUTURE DIRECTIONS: TECHNOLOGY…

- Computational model
  - SimSketch (Wouter van Joolignen) where children draw (computational) models based upon museums collections



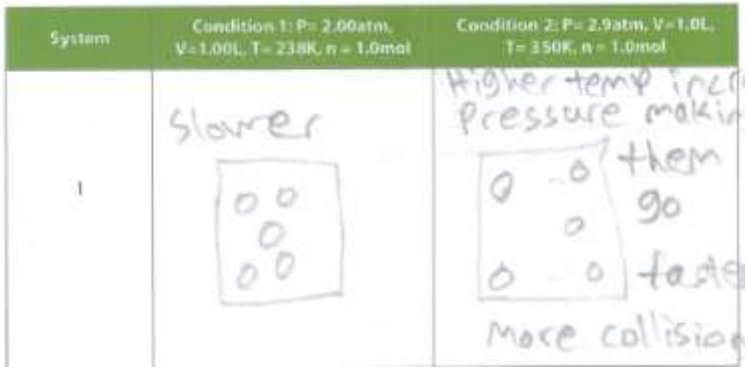
SOME FUTURE DIRECTIONS: TECHNOLOGY…

- Automatic marking of drawn exam questions or worksheets; e.g. Cogsketch (Ken Forbus) or BeSocratic (Melanie Cooper)



DRAWING FROM SIMULATIONS

- Can drawing help you learn from complex simulations and if so are these benefits stronger if you create predictive or reflective sketches (with Mike Stieff and Katharina Scheiter)



BUT IN ALL OF THESE AND OTHER STUDIES

- I will continue to try and understand the conditions under which drawing helps learning, why drawing helps learning and how we should analyze the drawings our studies.

THANKS

- Questions?
- Drawings ?