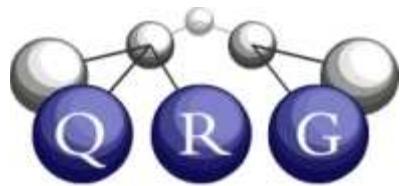
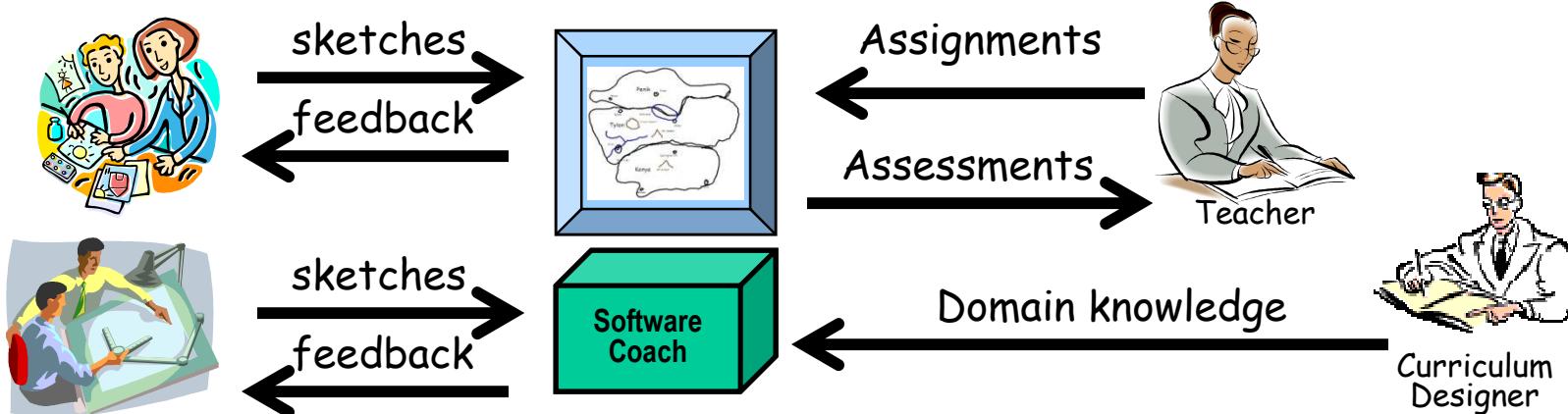


# CogSketch and Education



# How CogSketch Might Be Used in Education

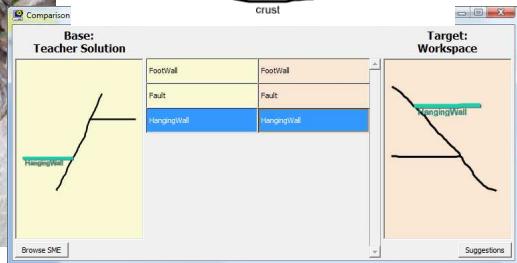
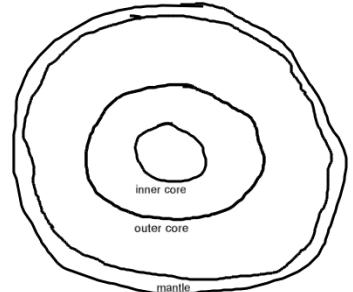
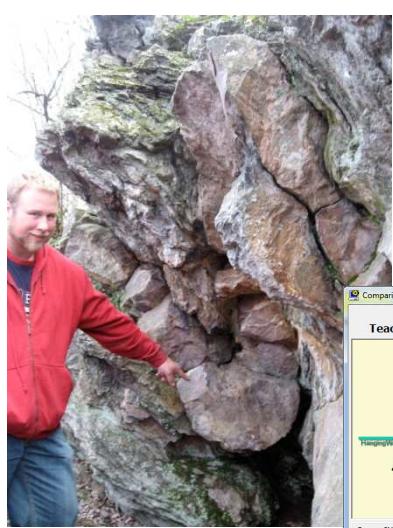


Platform for sketch-based educational software

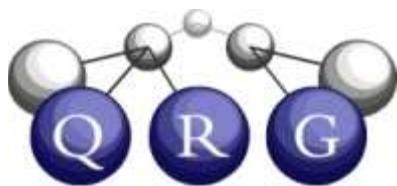
- Eventually, like a calculator
  - Always available
  - Useful across a broad variety of tasks
- But with more scaffolding
  - Access to intelligent tutors and coaches built in
    - Exploit science base developed by SILC

**Our Vision:**  
Sketch understanding software  
to help students learn could be  
made widely available within  
10 years

# Current CogSketch Education Projects



- Problem: Helping students understand spatial layouts and use terminology correctly
- Idea: Provide scaffolds in sketching exercises to coach students
- Software: *Worksheets*
- Kate Lockwood, Penny Yin

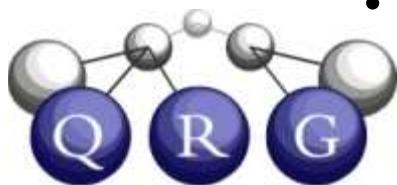


- Problem: Students have trouble using sketches to communicate their ideas
- Idea: Make a “crash test dummy” for students to practice with.
- Software: the *Design Buddy*
- Jon Wetzel

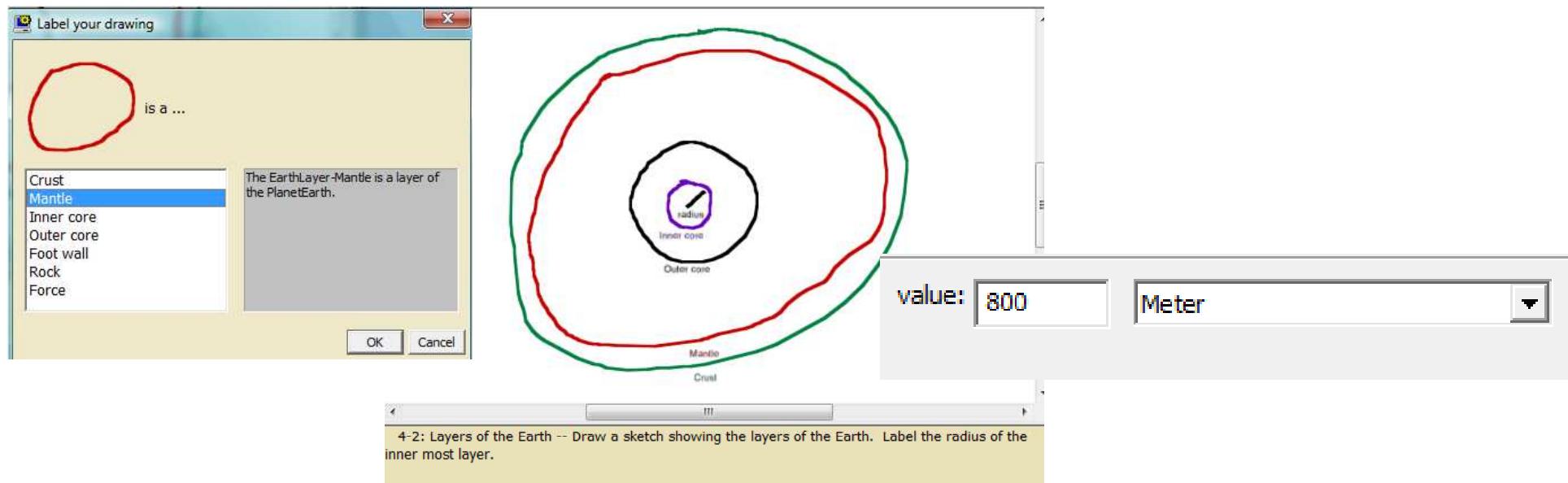


# Worksheets

- Simple pedagogical model
  - Student is given a sketching task
  - Doing the sketch helps learning by
    - Forcing the student to think about the topic
    - Retrieve potentially relevant knowledge
    - Filter by what makes sense to depict
    - Depict relevant knowledge in a way that communicates to someone
- CogSketch potentially provides value by
  - Giving advice, via analogy with teacher-drawn sketch
  - Proving teacher/experimenter with digital artifact that can be more deeply analyzed
    - Full timing data available



# Worksheet Example

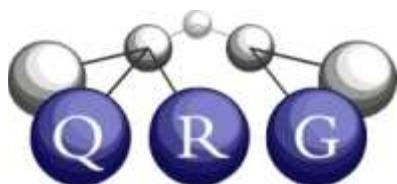


A screenshot of a "Comparison Results" window. It contains two main sections: "Base: Teacher Solution" and "Target: Workspace".  
**Base: Teacher Solution:** Shows a hand-drawn diagram of Earth's layers with three concentric circles. The innermost circle is labeled "Inner core" at the bottom. The middle circle is labeled "Mantle" at the bottom.  
**Target: Workspace:** Shows a hand-drawn diagram of Earth's layers with three concentric circles. The innermost circle is labeled "Inner core" at the bottom. The middle circle is labeled "Mantle" at the bottom.  
**Table:**  
A table comparing the teacher solution and workspace drawing:

radius	radius
Mantle	Mantle
Outer core	Outer core
Crust	Crust
Inner core	Inner core

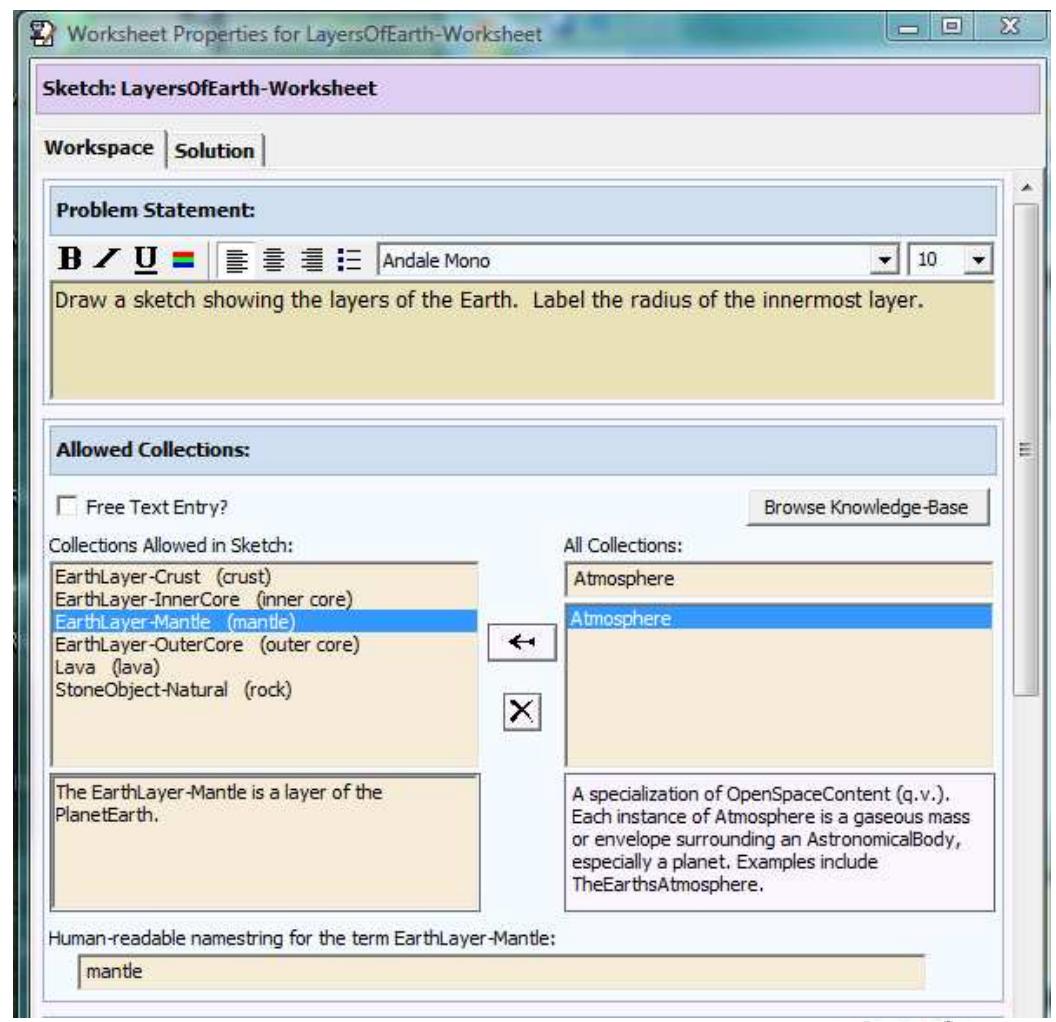
  
**Tutor Suggestions:**

You might think again about the size of the inner core radius.



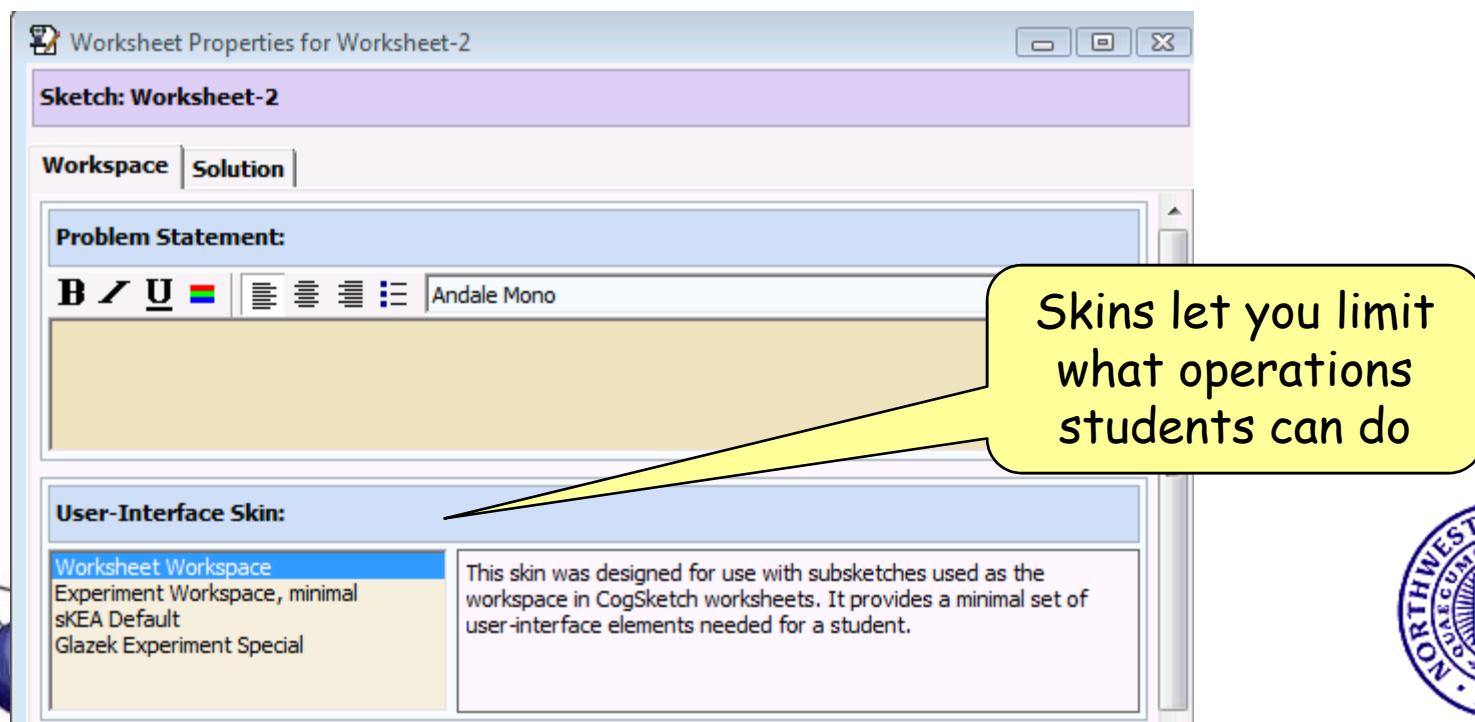
# Authoring Environment for Worksheets

- Can create new worksheets without programming
  - Sketch answer
  - Select included concepts
  - Mark important facts & provide advice
- Limitations
  - Only uses CogSketch default encoding strategies
  - Author works with KB concepts directly



# Making a New Worksheet: Startup

- Choose “New Worksheet” from the menu
- A new sketch plus the Worksheet Properties dialog appears
  - You can edit Worksheet properties for any worksheet, if you are in Developer mode



# Making a New Worksheet: Selecting relevant knowledge

- Add the allowed collections, relations, and annotations for your worksheet

Collections Allowed in Sketch:

CellMembrane (cell membrane)

You can change  
the short  
description a  
student will see

The stuff that encloses a cell

All Collections:

CellMembrane

Cell

Cell-Organization

CellCyde

CellDivision

CellEnlargementEvent

CellMembrane

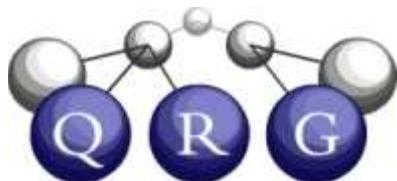
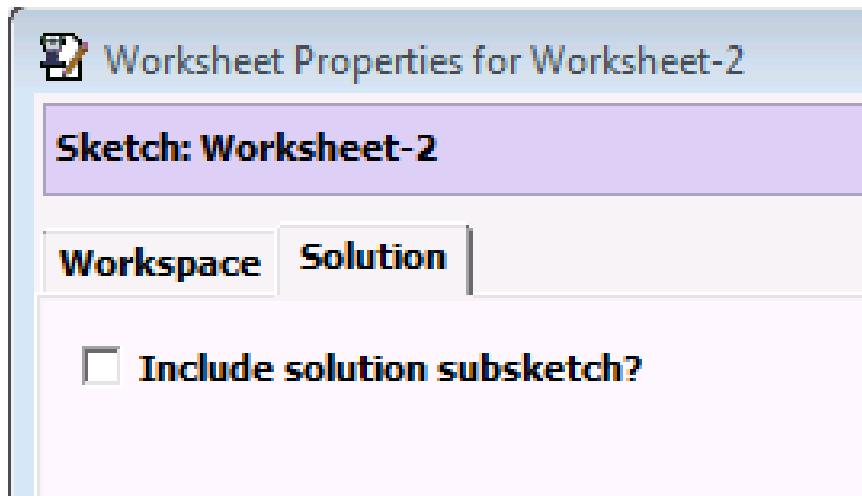
CellNucleus

Human-readable namestring for the term CellMembrane:

cell membrane

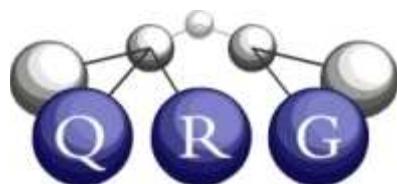
# Making a New Worksheet: Adding a solutions

- If you are including a solution, say so on the Solutions tab by clicking the check box
- Draw your solution on the Solution subsketch, and label it using the collections, relations, and annotations you already set up



# Making a New Worksheet: Providing Advice

- Select important facts
- Provide advice to be presented if analogous facts are not true in student sketch



**Tutoring Advice**

Selecting a glyph in the "Solution Glyphs" section below will show facts about the glyph that might be useful for tutoring. Choose which facts you want to be considered important.

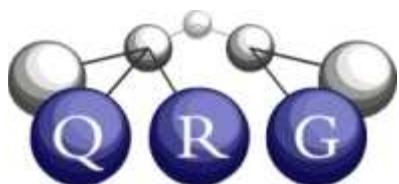
Solution Glyphs:	Update	Facts About Selected Glyph:
<ul style="list-style-type: none"><li>- teacher-layer<ul style="list-style-type: none"><li>□ Cell membrane (Object-3)</li><li>□ Nucleus (Object-4)</li><li>□ DNA (Object-5)</li></ul></li></ul>		<p>(containedGlyphGroupContainer (GlyphFn Object-3 User-Drawn-Sketch-Layer-3) (ContainedGlyphGroupFn (GlyphFn Object-3 User-Drawn-Sketch-Layer-3) (TheList (GlyphFn Object-4 User-Drawn-Sketch-Layer-3))))</p> <p>(containedGlyphGroupInsider (GlyphFn Object-4 User-Drawn-Sketch-Layer-3) (ContainedGlyphGroupFn (GlyphFn Object-3 User-Drawn-Sketch-Layer-3) (TheList (GlyphFn Object-4 User-Drawn-Sketch-Layer-3))))</p> <p>(isa Object-3 CellMembrane)</p>
		<b>Facts Important for Tutoring:</b> <p>(containedGlyphGroupContainer (GlyphFn Object-3 User-Drawn-Sketch-Layer-3) (ContainedGlyphGroupFn (GlyphFn Object-3 User-Drawn-Sketch-Layer-3) (TheList (GlyphFn Object-4 User-Drawn-Sketch-Layer-3))))</p> <p>(containedGlyphGroupContainer (GlyphFn Object-4 User-Drawn-Sketch-Layer-3) (ContainedGlyphGroupFn (GlyphFn Object-4 User-Drawn-Sketch-Layer-3) (TheList (GlyphFn Object-5 User-Drawn-Sketch-Layer-3))))</p>
<b>What tutoring advice should be associated with this fact?</b> You might reconsider the location of the DNA.		

# Making a New Worksheet – Numerical Annotations

- If your important fact involves the numerical value of an annotation, the fact you are looking for is *visualQuantityQuantitativeMeasurement*
- This fact will be associated with the glyph that was annotated (not the annotation itself)

**visualQuantityQuantitativeMeasurement** [1 fact]

   A (ist-Information BCASE-3428944319  
visualQuantityQuantitativeMeasurement  
((ConceptKnownAsFn "sizeOfCell")  
(GlyphFn Object-753 User-Drawn-Sketch-Layer-759))  
(Nanometer 100)))



## Tutoring Advice

Editing tutoring advice for the following fact:

```
(ist-Information BCASE-3428944319
  visualQuantityQuantitativeMeasurement
  ((ConceptKnownAsFn "sizeOfCell")
    (GlyphFn Object-753 User-Drawn-Sketch-Layer-759))
  (Nanometer 100)))
```

Object-753 = Cell membrane

Important for tutoring?

(Uncheck this if you no longer wish this fact to be used in tutoring.)

What tutoring advice should be associated with this fact?

Quantities mentioned in the fact:

- (Nanometer 100)

○ minimum allowed [optional]:

Tutoring advice that should be given if the student's value is less than the minimum allowed:

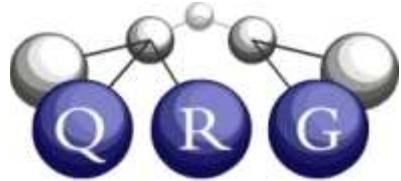
○ maximum allowed [optional]:

Tutoring advice that should be given if the student's value is greater than the maximum allowed:

OK

# Making a New Worksheet: Testing

- Save it
- Try it out



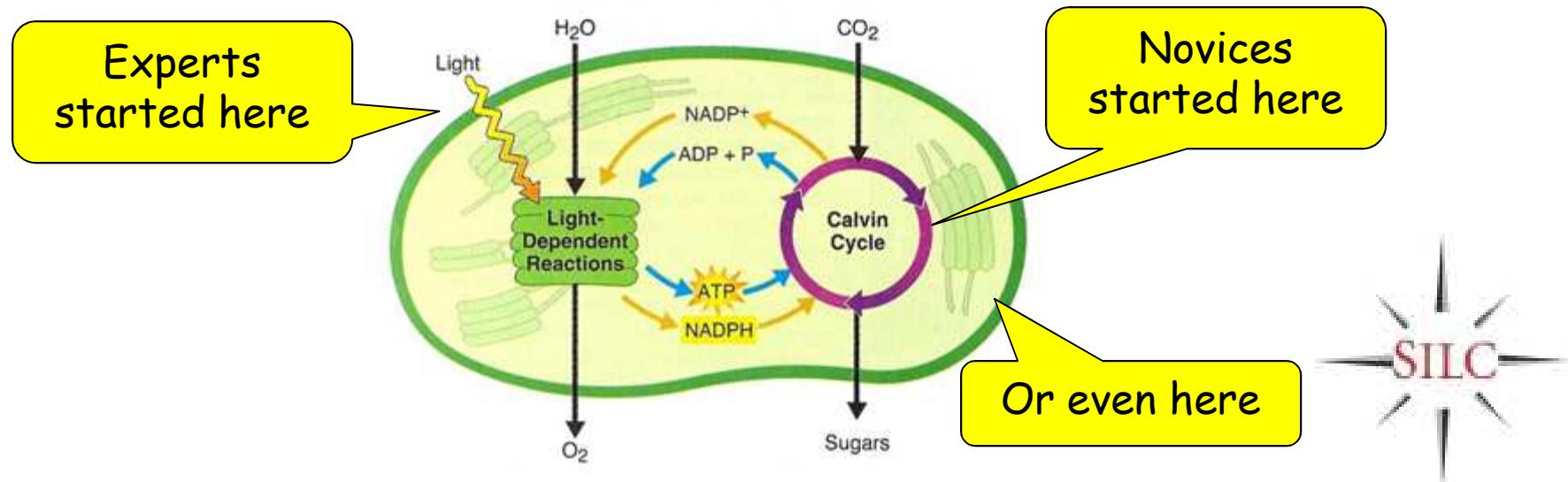
# Indirect measures of expertise

- Number of long pauses while copying equations inversely related to expertise
  - Cheng & Rojas-Anaya, 2007
- Distance between elements while copying equations reflects understanding of operator precedence in equations
  - Landy & Goldstone, 2007
- Conjecture: Properties of sketching can provide indirect measurement of expertise
  - CogSketch captures conceptually segmented ink, with timing information
  - Could gather data in experiments far easier than video
  - Could build assessment tools into classroom software



# Pilot study: Louis Gomez

- Task: College students copied figures from a standard high school textbook
  - 10 novices (no college science courses)
  - 10 experts (at least two college biology courses, mostly pre-med)
- Results: Experts started at the beginning of the process, novices stated with visually salient parts



# **GeoSketch study**

**(Jee et al, CogSci 09)**

- **Can CogSketch can be used to detect differences in geoscience knowledge?**

## **Participants:**

- 10 Novices—intro psychology students
- 10 Geoscience students—Geoscience undergrads and grad students

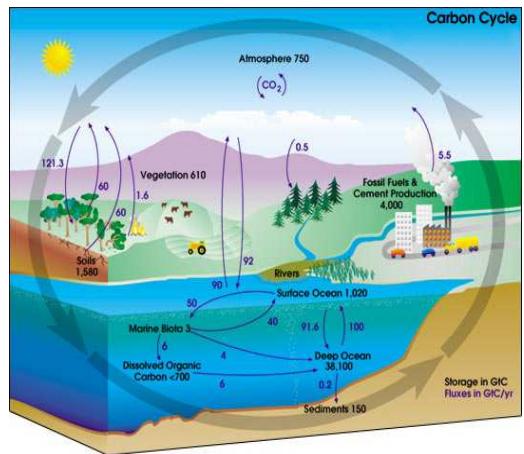
## **Method:**

- Participants sketched 9 geoscience images and 3 non-geoscience images
- 4 causal diagrams, 8 photographs
- Three different task conditions (4 sketches per condition; 3 minutes allotted per sketch):
  1. Tracing over image
  2. Copying while image present
  3. Reproducing from memory. Study for 30s, then reproducing the image from memory

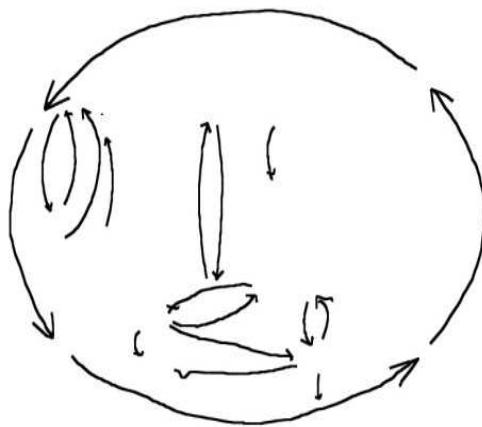
# Geo students include more relations

Jee, et al. Drawing on Experience: Use of sketching to evaluate knowledge of spatial scientific concepts (CogSci 2009)

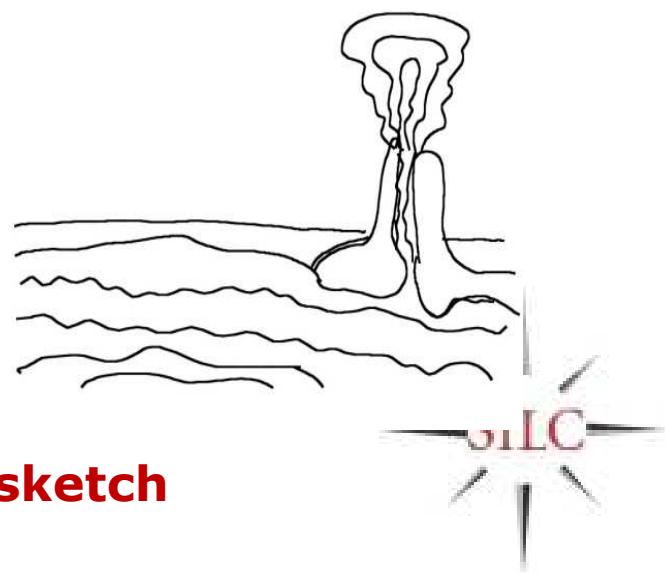
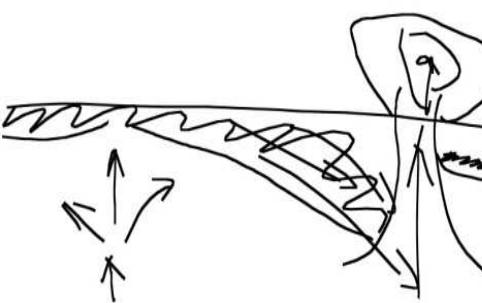
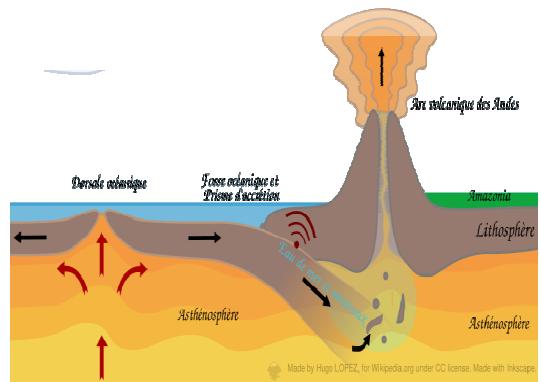
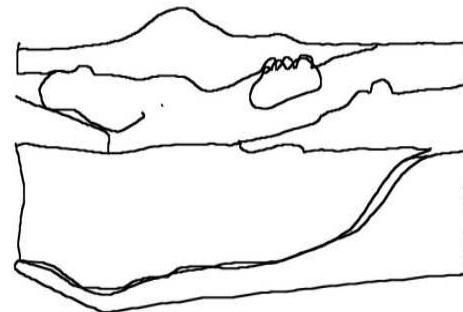
Causal/cycle diagram



Geo student sketch



Novice sketch



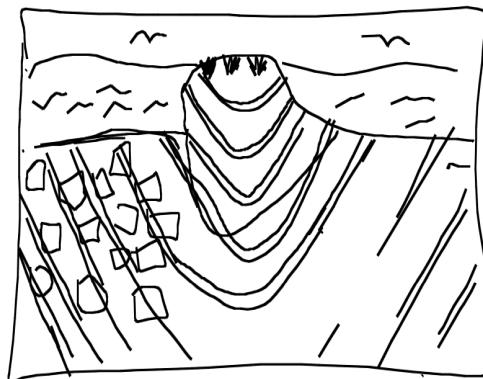
No differences for Control sketch

# Geo students include more key structures

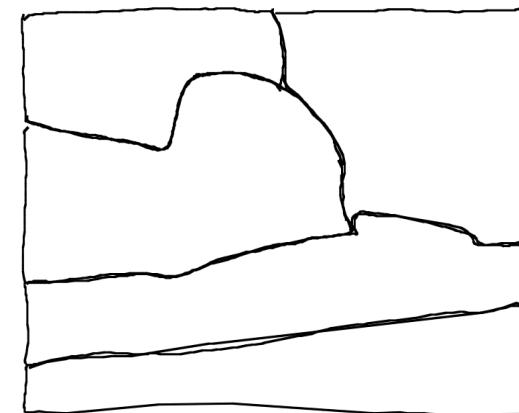
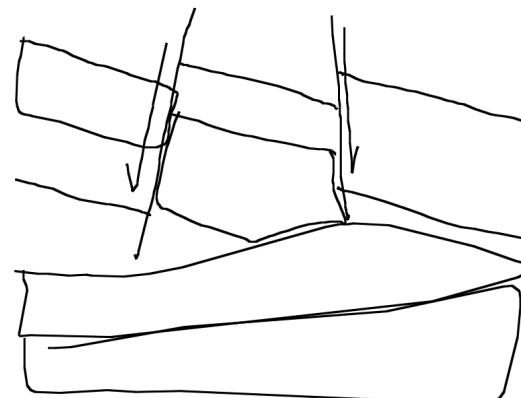
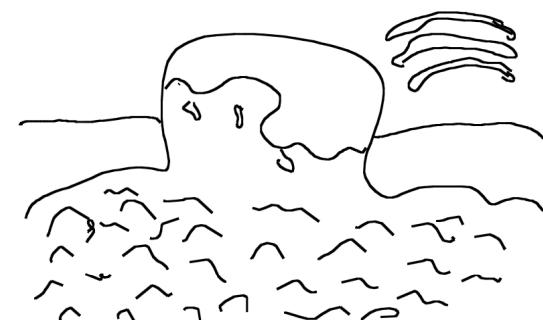
**Geo formation (key structures shown)**



**Geo student sketch**



**Novice sketch**



**No differences for Control sketches**

# Summary of results

## For causal diagrams:

- Geoscience students include more causal knowledge, relative to novices
  - They focus more on depicting relational information and less on depicting the objects present
  - They begin their sketches with causal/relational information more often than novices

## For photos of geological formations:

- Geoscience students include more geologically relevant structures
  - Relevant structures often idealized

Next steps: Extending CogSketch to automatically recognize & analyze these properties,  
+ more experiments,  
+ first use of worksheets in coursework, this fall



# Design Buddy: Setting and Problem

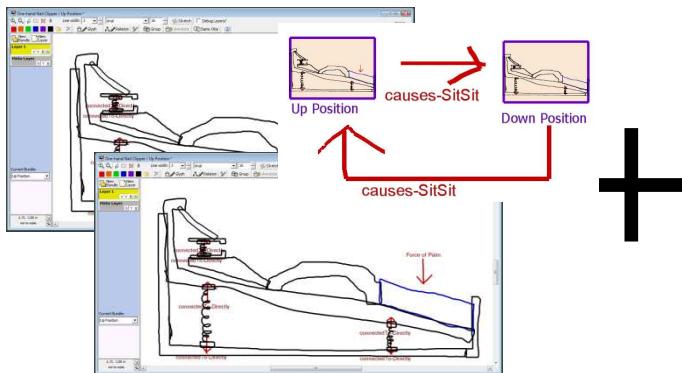
Engineering Design and Communication Course  
at Northwestern University



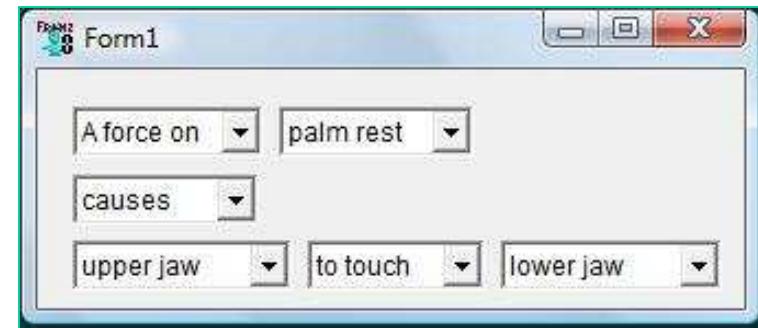
**Problem:**  
**Students have trouble using sketches to communicate**

# Goal: Design Buddy

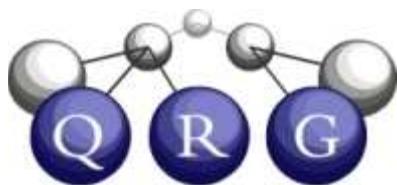
- Given: An explanation consisting of...



Sketches  
(currently)

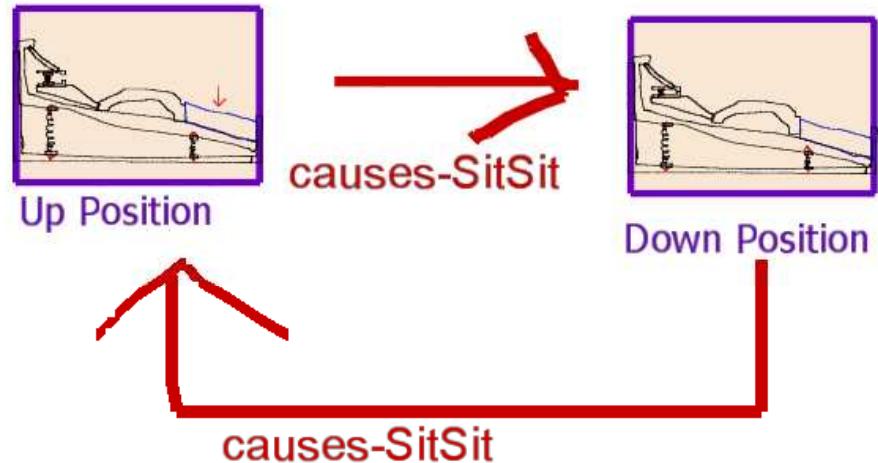


- Goal: Provide feedback about the student's explanation
  - Could the system work that way?
  - How can the explanation be improved?



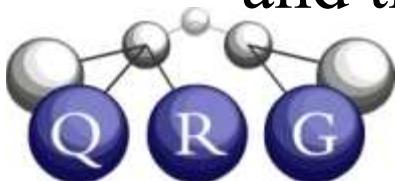
# A Typical EDC Project

- Projects meet a customer's need
  - E.g. Help a stroke victim perform a task with only one arm/hand.

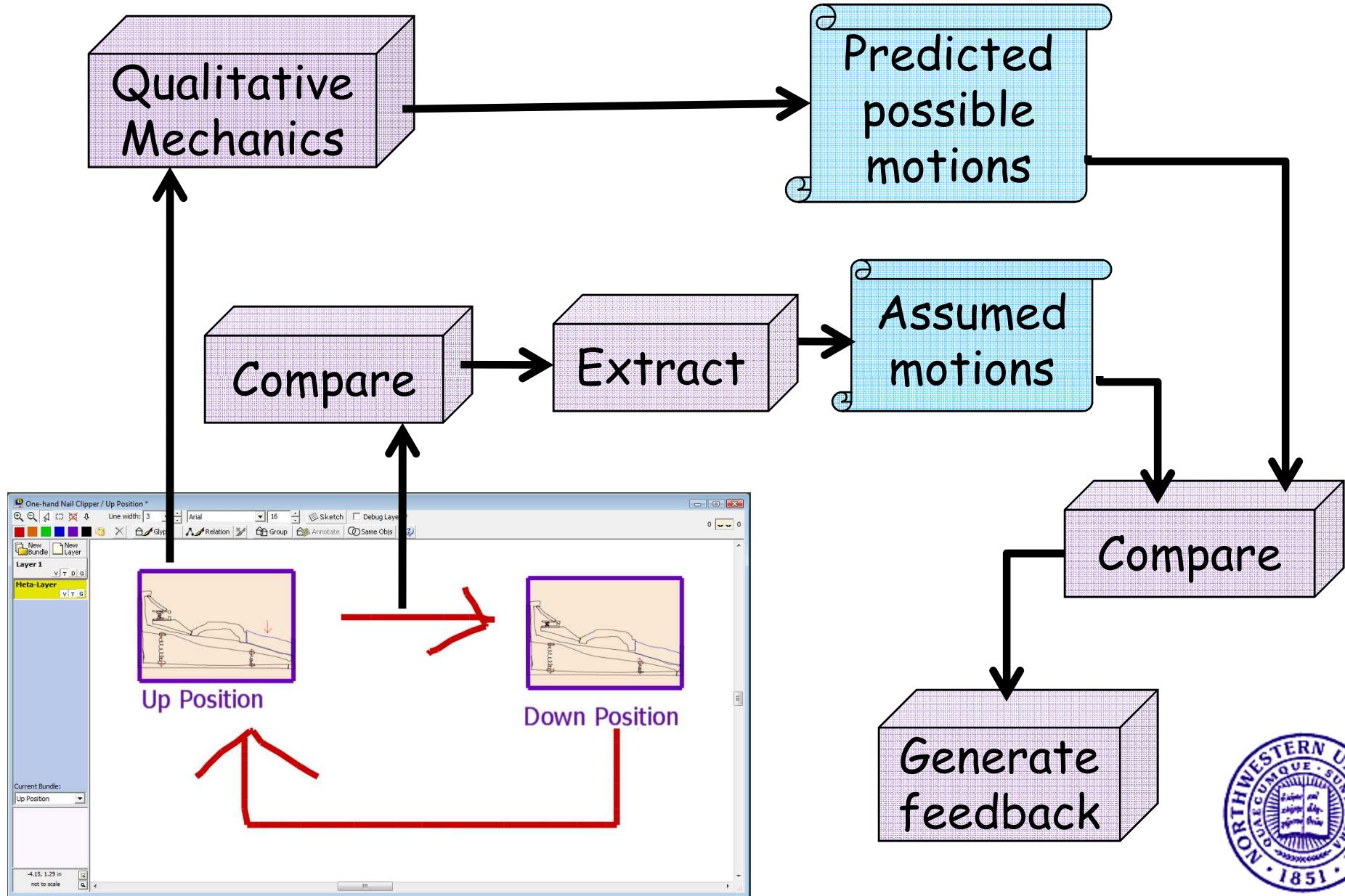


Device for clipping fingernails with one hand

- Novel projects every quarter
- Students must design (including sketch) device and then build prototype

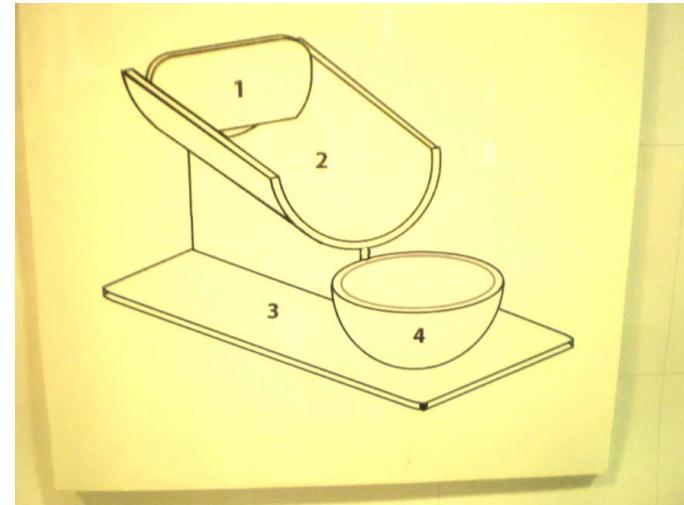


# How it currently works

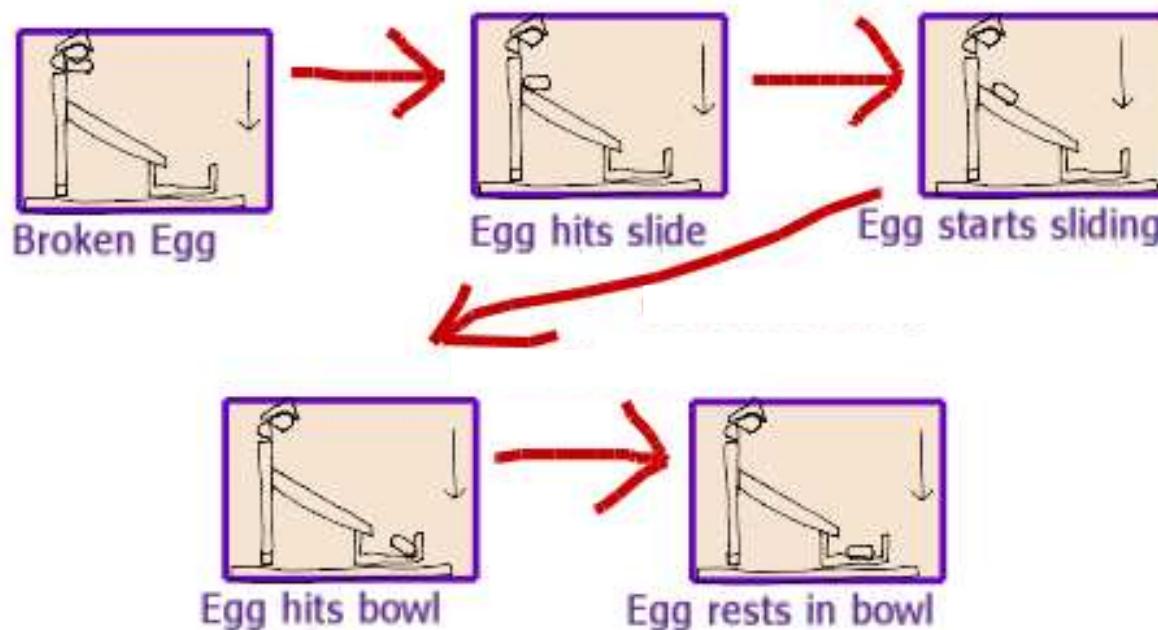
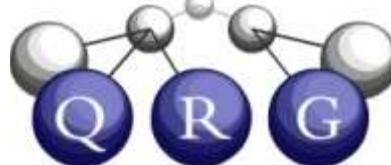


# Coverage Experiment: Design Buddy

- Out of 39 student design projects:
  - 19 didn't involve mechanics
  - 16 handled by CogSketch using QM reasoning
  - 4 involved 3D beyond its current capabilities



See  
Wetzel &  
Forbus  
IAAI09  
paper for  
details



# Summary

- Worksheets are designed to help students learn spatial phenomena, especially layouts
  - Could be used as homework assignments or off-line tutorials
  - Even simple tasks, like copying a diagram, may provide useful assessment data
- CogSketch can potentially be combined with other AI techniques to do sophisticated tutoring in spatial domains
  - Design Buddy is a test of this hypothesis, underway

