CogSketch and Education
How CogSketch Might Be Used in Education

• 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
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.

You can change the short description a student will see.

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
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)

• You can specify a range of acceptable values

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**Tutoring Advice**

Editing tutoring advice for the following fact:

```
{ist-Information $Case-342894319
 (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):
  - Maximum allowed [optional]:

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

[Blank field]

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

[Blank field]

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
• 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


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)

  +

  Language-like input (end of summer)

- 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.

• Novel projects every quarter
• Students must design (including sketch) device and then build prototype
How it currently works

Qualitative Mechanics

Predicted possible motions

Assumed motions

Compare

Extract

Generate feedback

Up Position

Down Position
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