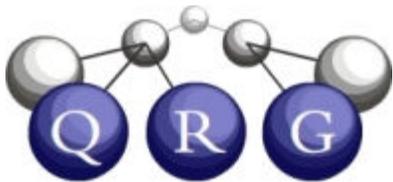
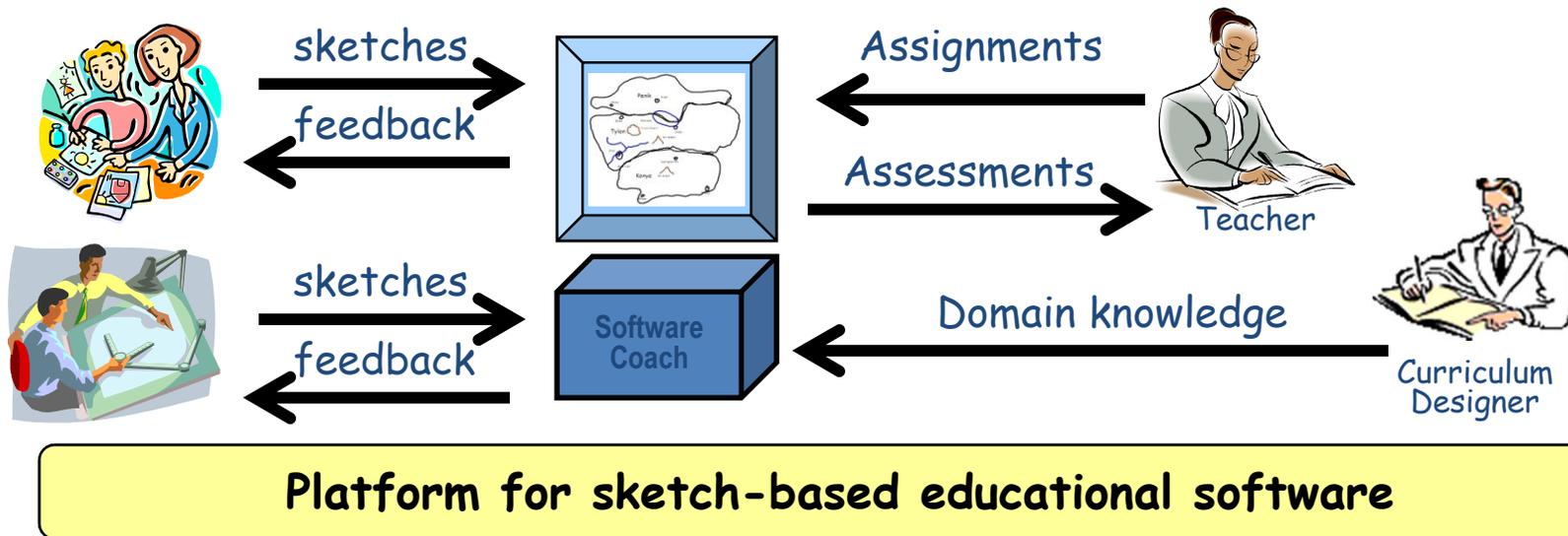


CogSketch and Education



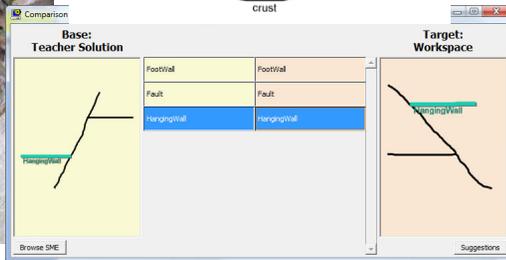
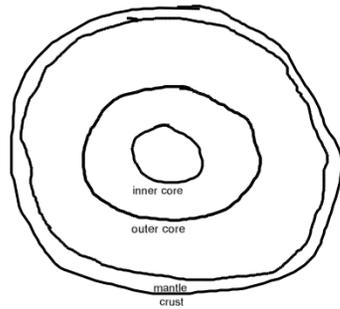
How CogSketch Might Be Used in Education



- 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

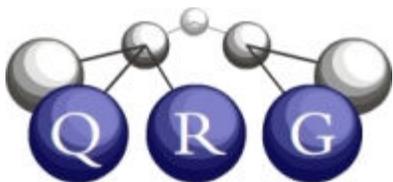
Our Vision:
Sketch understanding software to help students learn could be made widely available within 5 years

Current CogSketch Education Projects



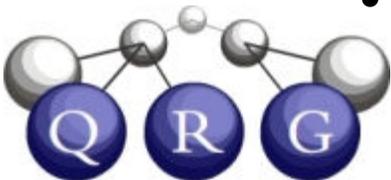
- Problem: Helping students understand spatial layouts and use terminology correctly
- Idea: Provide scaffolds in sketching exercises to coach students
- Software: *Worksheets*
- Maria Chang

- Problem: Students have trouble using sketches to communicate their ideas
- Idea: Make an explanation coach for students to practice with.
- Software: the *Design Coach*
- Jon Wetzel



Worksheets

- Simple pedagogical model
 - Student is given a sketching task
 - Doing the sketch should help 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

1_Greenhouse-Effect / Workspace

Layer 1
V T G

Meta-Layer
V T G

Current Subsketch:
Workspace

Feedback

-2.56, -0.40 in
zoom = 1.00x

Draw a diagram that shows the greenhouse effect.

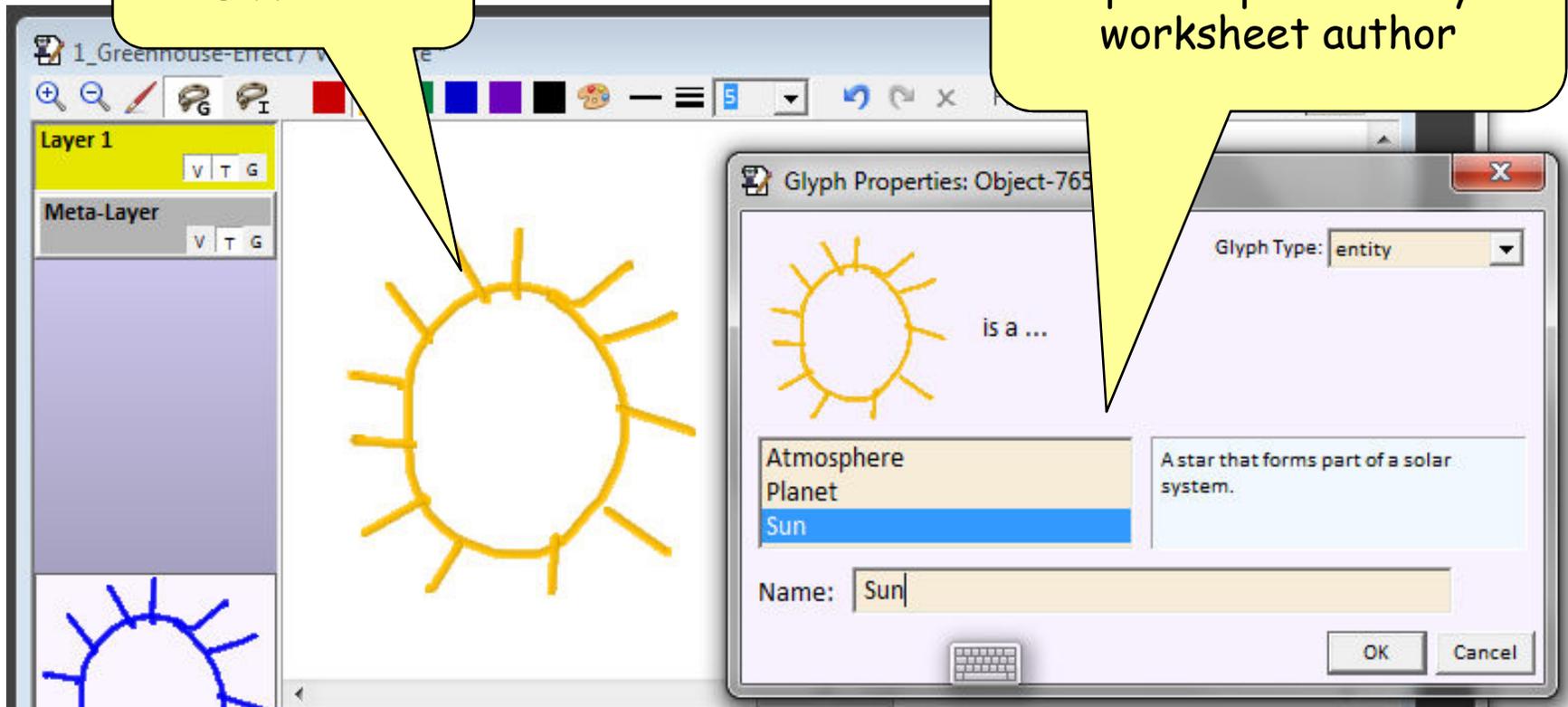
- First, draw **3 entities**:
 - the Sun
 - the Earth
 - the Earth's atmosphere
- Next, draw the radiation emitted and absorbed across the 3 entities. There are two kinds of radiation: *short wave radiation* includes ultra-violet and visible light and *long wave radiation* includes infrared. Draw **3 relation arrows** to show:
 - radiation going from the Sun to the Earth
 - radiation going from the Earth to the Earth's atmosphere
 - radiation going from the Earth's atmosphere to the Earth

Student reads directions

Worksheet Example: Draw and Label

Student draws glyphs...

...and labels them, using options provided by worksheet author



Worksheet Example: Relations

The screenshot shows a software interface for creating a diagram. The main workspace contains a hand-drawn diagram of the greenhouse effect. On the left is a yellow sun with rays, labeled 'Sun'. On the right is a blue and green Earth, labeled 'Earth'. A black arrow points from the Sun to the Earth, labeled 'Long wave'. Three black arrows point from the Earth back towards the Sun, each labeled 'Long wave'. The Earth is enclosed in a grey oval labeled 'Earth's Atmosphere'. A yellow callout bubble points to the arrows with the text 'Student draws and labels relations'. Below the main workspace is a 'Feedback' panel with a 'Feedback' button and some numerical values. A 'Glyph Properties: Long wave' dialog box is open in the foreground. It has a 'Glyph Type' dropdown set to 'relation'. Below this, it says 'is the following relation ...' with a small arrow icon. There are two rows of icons and labels: a sun icon with a dropdown menu showing 'Sun', and an Earth icon with a dropdown menu showing 'Earth'. At the bottom of the dialog, the text reads 'Sun emits long wave radiation to Earth.' and there are 'OK' and 'Cancel' buttons. A yellow callout bubble points to the 'Feedback' button with the text 'The student hits feedback and...'. The software interface also shows a toolbar with various drawing tools and a 'Finish Glyph' button.

Student draws and labels relations

Long wave

Long wave

Long wave

Earth's Atmosphere

Earth

Sun

Feedback

Long wave

Short wave

is the following relation ...

Sun

Earth

Sun emits long wave radiation to Earth.

OK Cancel

The student hits feedback and...

Worksheet Example: Suggestions

Tutor makes suggestions by comparing solution sketch and student's sketch.

Tutor Suggestions

Suggestions for Sketch sc-demo-greenhouse

Selecting a suggestion will highlight the associated glyphs.

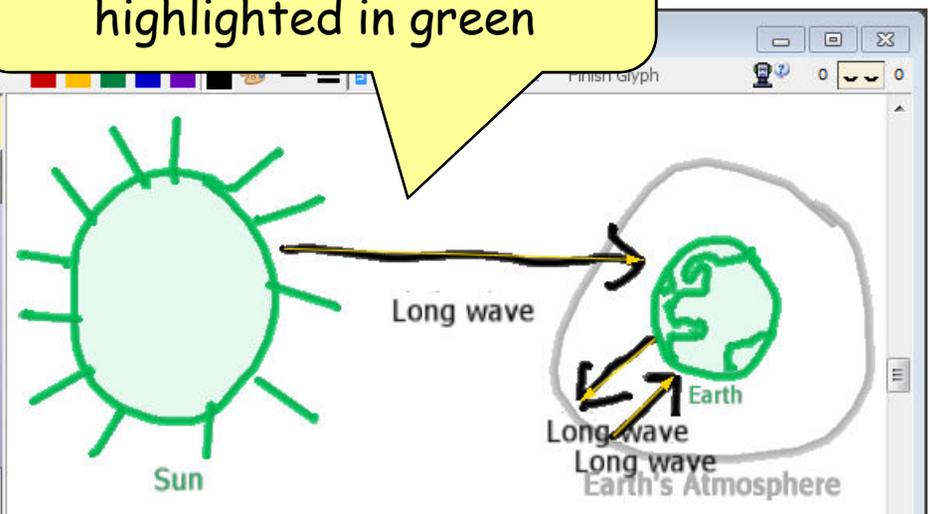
- There is supposed to be radiation emitted from the Sun to the Earth and it is a specific kind of radiation. Short wave radiation includes UV and visible light. Long wave radiation includes infrared. Which kind do you think it is?

See more suggestions...

Update suggestions

Hide missing entity suggestions?

When a student selects a suggestion, the glyphs are highlighted in green



Worksheet Example: Success!

The image shows a screenshot of a sketching application window titled "sc-demo-greenhouse / Workspace". The application interface includes a toolbar with various drawing tools and a layer management panel on the left. The main workspace contains a hand-drawn diagram of the greenhouse effect. A yellow sun is on the left, with a yellow arrow labeled "Short wave" pointing towards a blue circle representing "Earth". The Earth is surrounded by a grey oval representing "Earth's Atmosphere". Two yellow arrows labeled "Long wave" point from the Earth towards the atmosphere. The diagram is overlaid on a purple "Meta-Layer".

In the foreground, a "Tutor Suggestions" window is open. It displays a speech bubble with the text "Your sketch looks good to me!" and a small robot icon. Below the speech bubble are buttons for "See more suggestions...", "Update suggestions", and a checkbox labeled "Hide missing entity suggestions?".

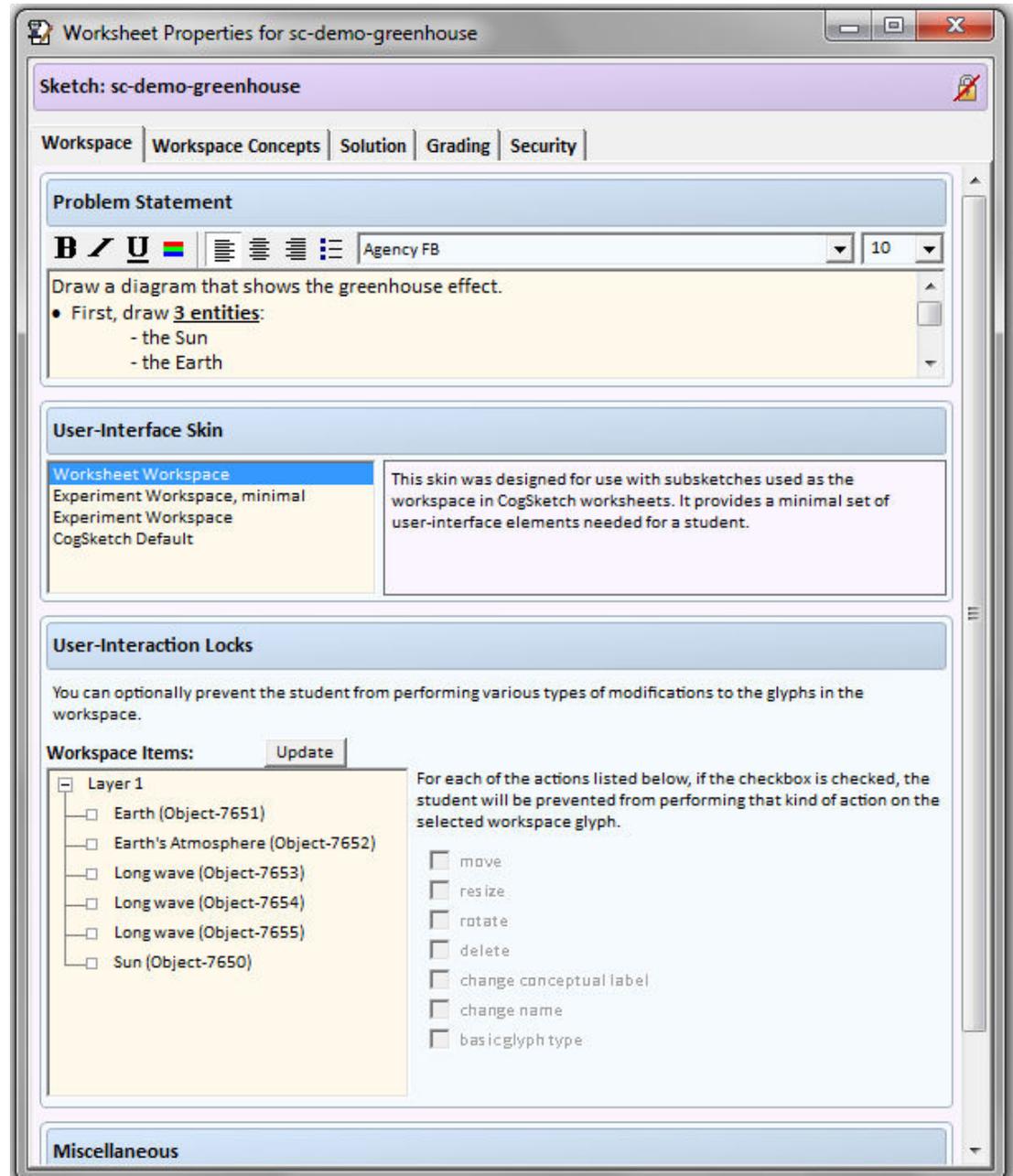
At the bottom of the application window, a text area contains the following text:

house effect.

l absorbed across the 3 entities. There are two kinds of
s ultra-violet and visible light and *long wave radiation*
ows to show:

Authoring Environment for Worksheets

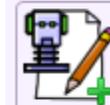
- Can create new worksheets without programming
 - Sketch answer
 - Select included concepts
 - Mark important facts & provide advice
- Limitation
 - Authoring currently requires familiarity with the CogSketch knowledge base (outlined later)



Making a New Worksheet: Startup

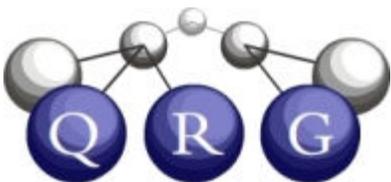
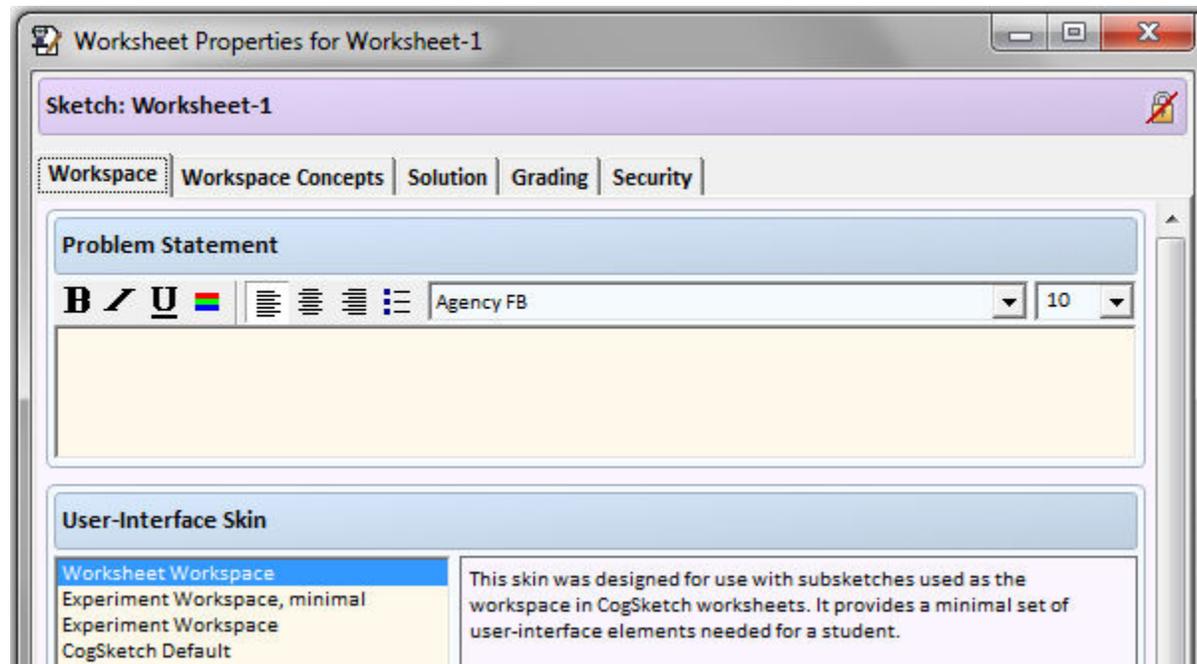
- Click “Create New Worksheets” on the start screen (or choose “New Worksheet” from menu)
- A new sketch plus the Worksheet Properties dialog appears
 - **Edit** menu / **Worksheet Property Editor** can also be used to open the property dialog.

For Experts



Create New Worksheet

Create a new worksheet for use in classes.



Making a New Worksheet: Problem Statement and UI Skin

The problem statement gives instructions to the students.

The skin determines which user-interface controls are available.

User-interaction locks can be used to prevent the user from performing actions on glyphs provided on the workspace subsketch.

Worksheet Properties for 1_Greenhouse-Effect

Sketch: 1_Greenhouse-Effect

Workspace Workspace Concepts Solution Grading Security

Problem Statement

B / U [Color Picker] [List Icons] Agency FB

Draw a diagram that shows the greenhouse effect.

- First, draw **3 entities**:
 - the Sun
 - the Earth

User-Interface Skin

| | |
|-------------------------------|--|
| Worksheet Workspace | This skin was designed for use with subsketches used as the workspace in CogSketch worksheets. It provides a minimal set user-interface elements needed for a student. |
| Experiment Workspace, minimal | |
| Experiment Workspace | |
| CogSketch Default | |

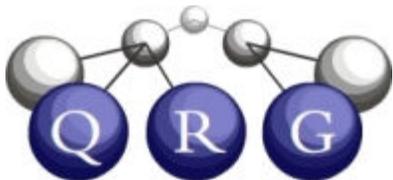
User-Interaction Locks

You can optionally prevent the student from performing various types of modifications to the glyphs in the workspace.

Workspace Items: [Update]

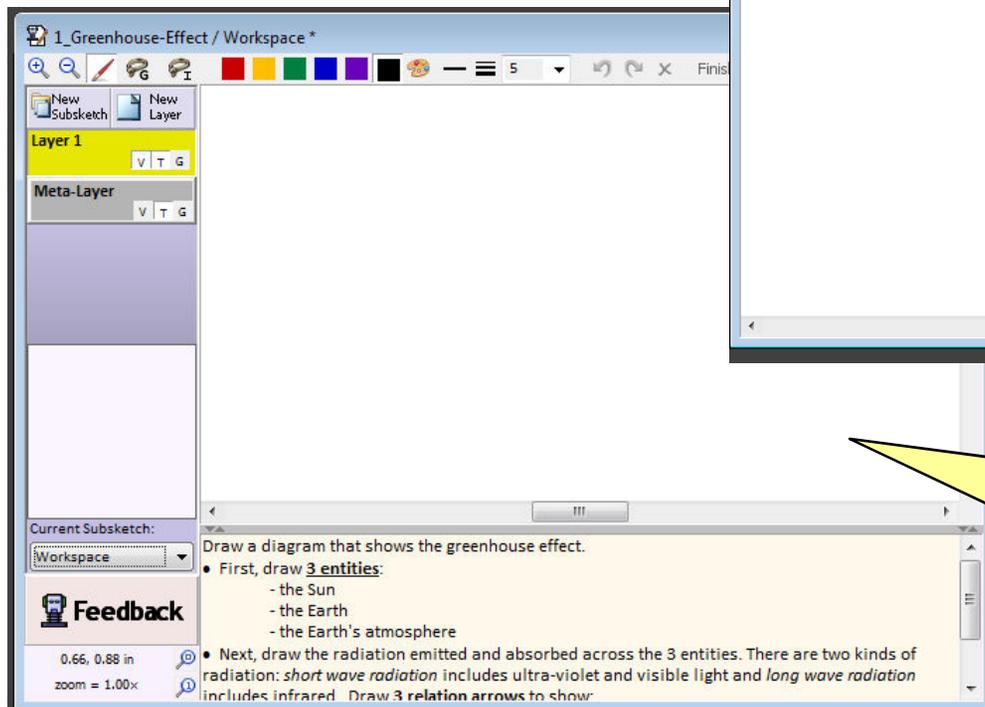
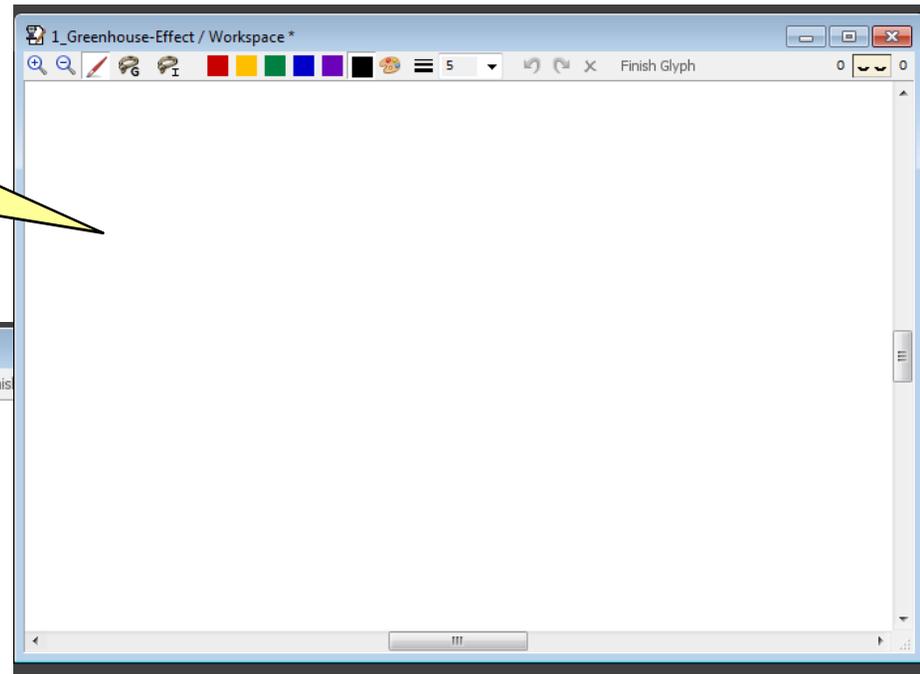
| | |
|----------------------------------|---|
| <input type="checkbox"/> Layer 1 | For each of the actions listed below, if the checkbox is checked student will be prevented from performing that kind of action on selected workspace glyph. |
|----------------------------------|---|

- move
- resize
- rotate
- delete
- change conceptual label

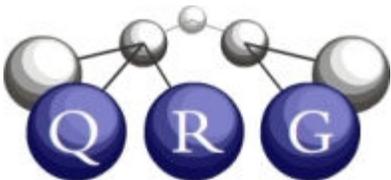


Example Skins

Experiment Workspace,
minimal



Worksheet Workspace
(default skin)



Making a New Worksheet: Selecting relevant knowledge

Workspace | **Workspace Concepts** | Solution | Grading | Security

Allowed Collections

Free Text Entry?

Collections Allowed in Sketch:

- Atmosphere (atmosphere)
- Planet (planet)**
- Sun (sun)

All Collections:

Browse Knowledge-Base

A body in an orbit around a star that is large enough for its own gravity to make it mostly round and has mostly cleared its neighborhood of smaller natural objects.

Human-readable name for the term Planet:

planet

Allow extra glyphs of this type?

In this tab, you select relevant collections for labeling glyphs, as well as relations and annotations

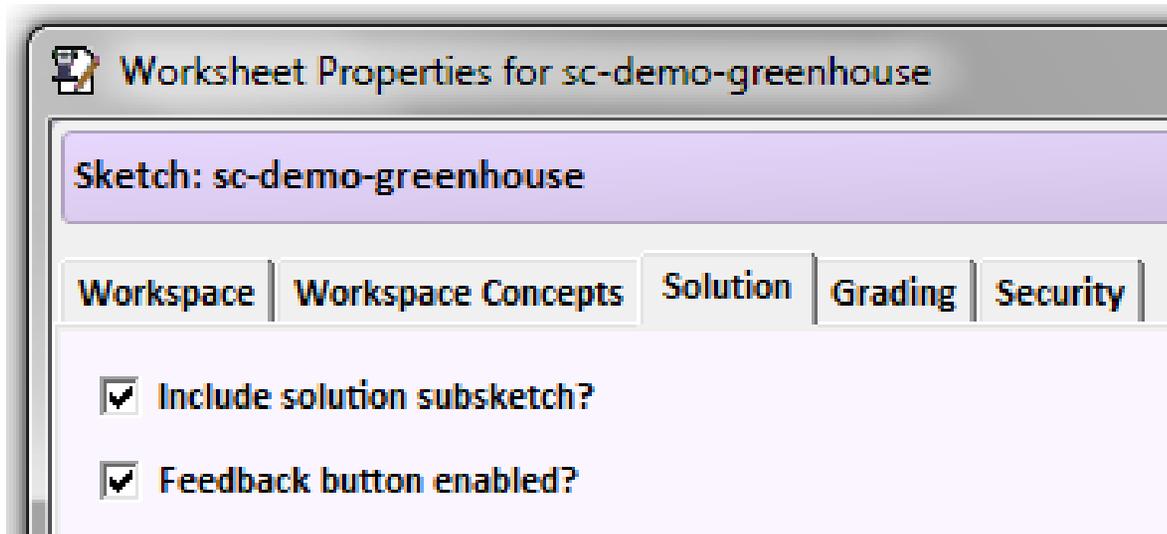
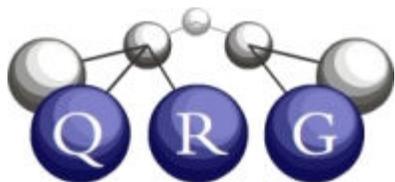
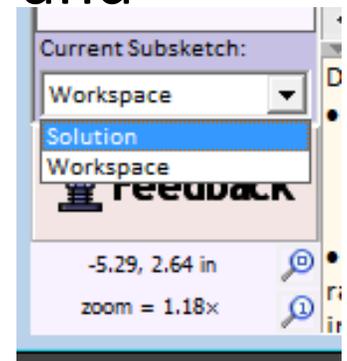
Search for new collections by name here

You can change the short description a student will see

Scroll down for relations and annotations

Making a New Worksheet: Adding a solution

- If you are including a solution, say so on the Solutions tab by clicking the check box
- Draw your solution on the Solution subs sketch, and label it using the collections, relations, and annotations you set up in the previous tab
- You may also remove the feedback button if desired (e.g. for an experiment or an exam)



Making a New Worksheet: Two Types of Advice

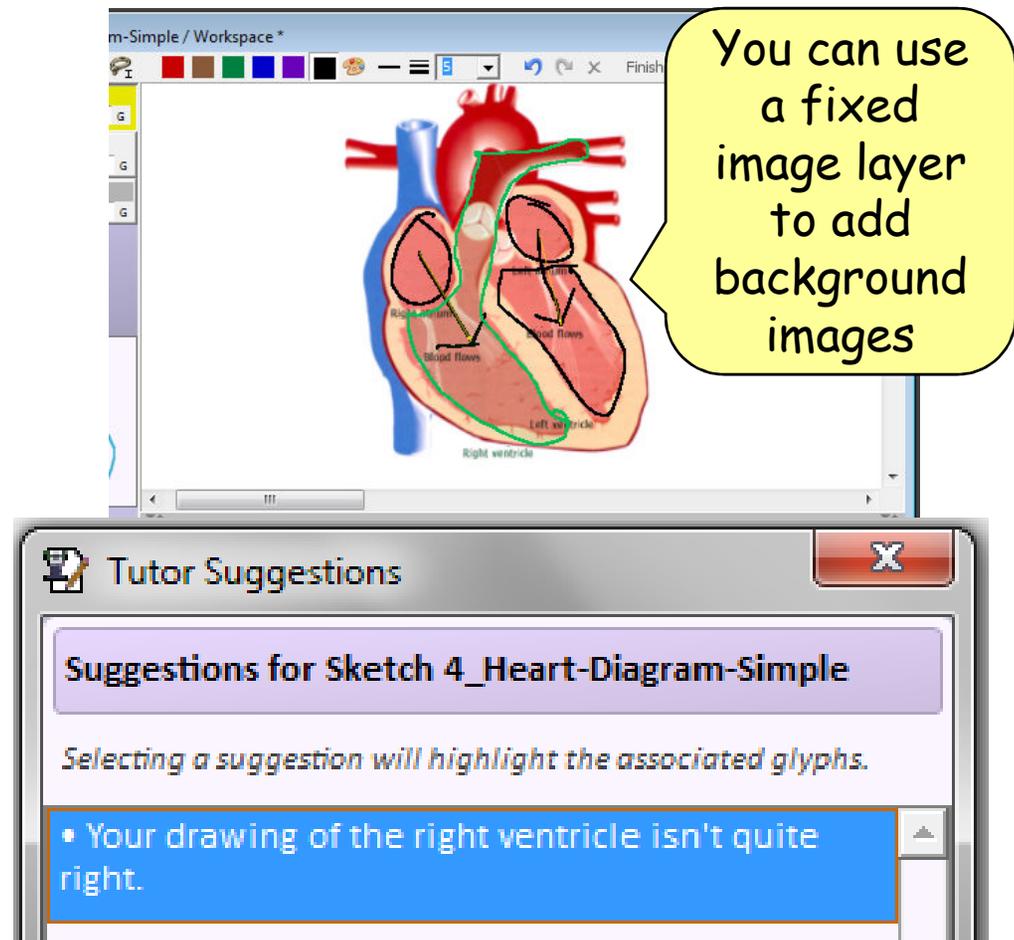
Select Important Facts

Could be any fact in sketch, for example:

- Relation arrows (e.g. greenhouse example)
- Spatial information (e.g. containment)
- Numerical values on annotations
- What concept a glyph represents (i.e. its label)

Quantitative ink comparison

Ink in student sketch vs ink in solution sketch



The screenshot shows a software window titled 'm-Simple / Workspace *' containing a diagram of a heart. The heart is colored in red and blue, with labels for 'Right ventricle', 'Left ventricle', and 'Blood flows'. A student's sketch is overlaid on the diagram, showing a green outline of the heart and some black lines. A yellow callout bubble points to the diagram with the text: 'You can use a fixed image layer to add background images'. Below the diagram is a 'Tutor Suggestions' window. The window has a title bar with a close button. The main content area has a purple header: 'Suggestions for Sketch 4_Heart-Diagram-Simple'. Below the header is a line of text: 'Selecting a suggestion will highlight the associated glyphs.' At the bottom of the window is a blue message box with the text: '• Your drawing of the right ventricle isn't quite right.'

Making a New Worksheet: Providing Advice for Facts

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

The screenshot shows a software interface with a menu bar at the top containing 'Workspace', 'Workspace Concepts', 'Solution', 'Grading', and 'Security'. The main window has a title bar 'Tutoring Advice: Facts Important for Tutoring'. Below the title bar is a text box: '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.' The interface is divided into two main sections: 'Solution Items:' and 'Facts About Selected Item:'. The 'Solution Items:' section has an 'Update' button and a tree view under 'Layer 1' with items: 'Sun (Object-7576)', 'Planet (Object-7577)', 'Atmosphere (Object-7578)', 'Short wave emission (Object-7579)', 'Long wave emission (Object-7591)', and 'Long wave emission (Object-7592)'. The 'Planet (Object-7577)' item is selected. The 'Facts About Selected Item:' section shows a list of facts, with '(emitsLongWaveRadiationTo Object-7578 Object-7577)' selected. Below this is a section 'Facts Important for Tutoring:' with a green arrow icon and a list of facts: '(emitsShortWaveRadiationTo Object-7576 Object-7577)', '(emitsLongWaveRadiationTo Object-7577 Object-7578)', and '(emitsLongWaveRadiationTo Object-7578 Object-7577)'. The first fact is selected. At the bottom, there is a text box with the question: 'What tutoring advice should be associated with this fact?' and the answer: 'There is supposed to be radiation emitted from the Sun to the Earth and it is a specific kind of radiation. Short wave radiation includes UV and visible light. Long wave radiation includes infrared. Which kind do you think it is?'

Making a New Worksheet: Providing Advice for Numerical Annotations

Solution Items: Update

- Layer 1
 - Sun (Object-7576)
 - Planet (Object-7577)
 - Atmosphere (Object-7578)
 - Short wave emission (Object-7579)
 - Long wave emission (Object-7591)
 - Long wave emission (Object-7592)

(visualQuantityQuantitativeMeasurement
(QuantityDenotedByAnnotation Object-7657
LengthIndicator (TheSet Object-7576)
(Kilometer 696000))

If your important fact involves a numerical value, the fact you are looking for is:
visualQuantityQuantitativeMeasurement

This fact will be associated with the glyph that was annotated (not the annotation itself)

What tutoring advice should be associated with this fact?

Quantities mentioned in the fact:

(Kilometer 696000)

Minimum Allowed (optional):

Maximum Allowed (optional):

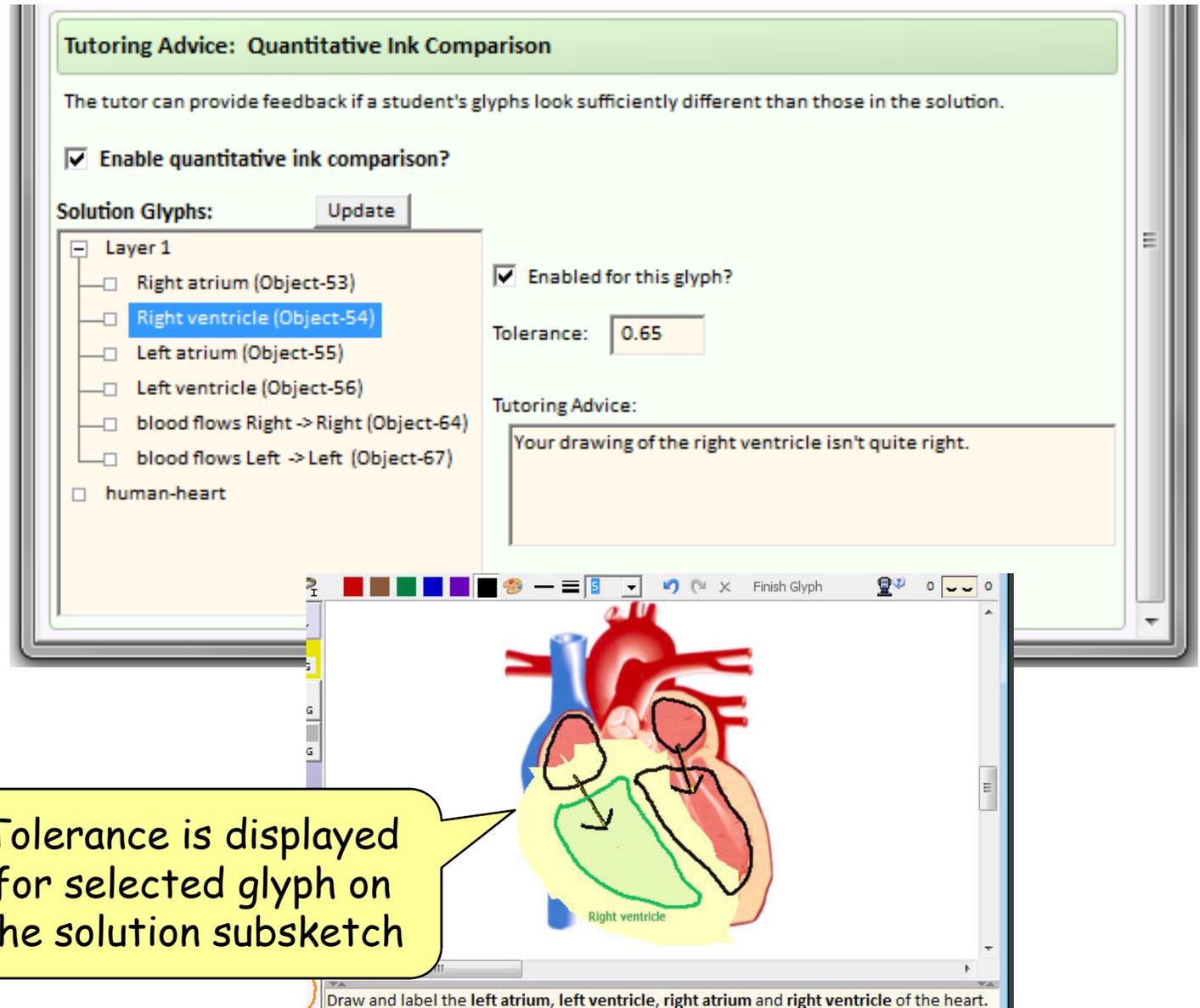
Advice that should be given if the student's value is less than the minimum allowed (optional):

Advice that should be given if the student's value is greater than the maximum allowed (optional):

You can specify a range of acceptable values and advice for each quantity

Making a New Worksheet: Providing Advice for Q. Ink Comparisons

- Select glyphs that need to be in the right place
- Specify tolerance and advice
- Advice given if glyph looks different enough



Tutoring Advice: Quantitative Ink Comparison

The tutor can provide feedback if a student's glyphs look sufficiently different than those in the solution.

Enable quantitative ink comparison?

Solution Glyphs:

- Layer 1
 - Right atrium (Object-53)
 - Right ventricle (Object-54)
 - Left atrium (Object-55)
 - Left ventricle (Object-56)
 - blood flows Right -> Right (Object-64)
 - blood flows Left -> Left (Object-67)
- human-heart

Enabled for this glyph?

Tolerance:

Tutoring Advice:

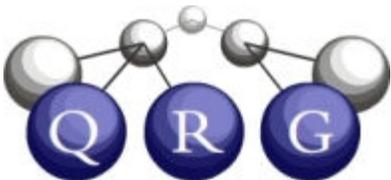
Your drawing of the right ventricle isn't quite right.

Tolerance is displayed for selected glyph on the solution subs sketch

Draw and label the left atrium, left ventricle, right atrium and right ventricle of the heart.

Making a New Worksheet: Testing

- Save first!
- Switch to workspace and sketch a perfect solution
 - Verify that solution works
- Then try:
 - Deleting glyphs
 - Moving glyphs
 - Resizing/rotating glyphs
 - Making the most bizzare variations you can think of
- Do pilot testing on friends and small groups of students



Making a New Worksheet: Grading

Worksheet Properties for sc-demo-greenhouse

Sketch: sc-demo-greenhouse

Workspace | Workspace Concepts | Solution | **Grading** | Security

Normalize To: points (60 points total before normalization)

Missing Glyphs 60 points [100.0%]

The glyphs listed below were mentioned in the facts important for tutoring and/or given quantitative ink comparison tolerances. For each of these glyphs, points can be awarded if the student has included those glyphs in their sketch.

| | |
|--------------------------|----|
| Atmosphere (Object-7578) | 20 |
| Planet (Object-7577) | 20 |
| Sun (Object-7576) | 20 |

Multiple grading criteria available (scroll down for more)

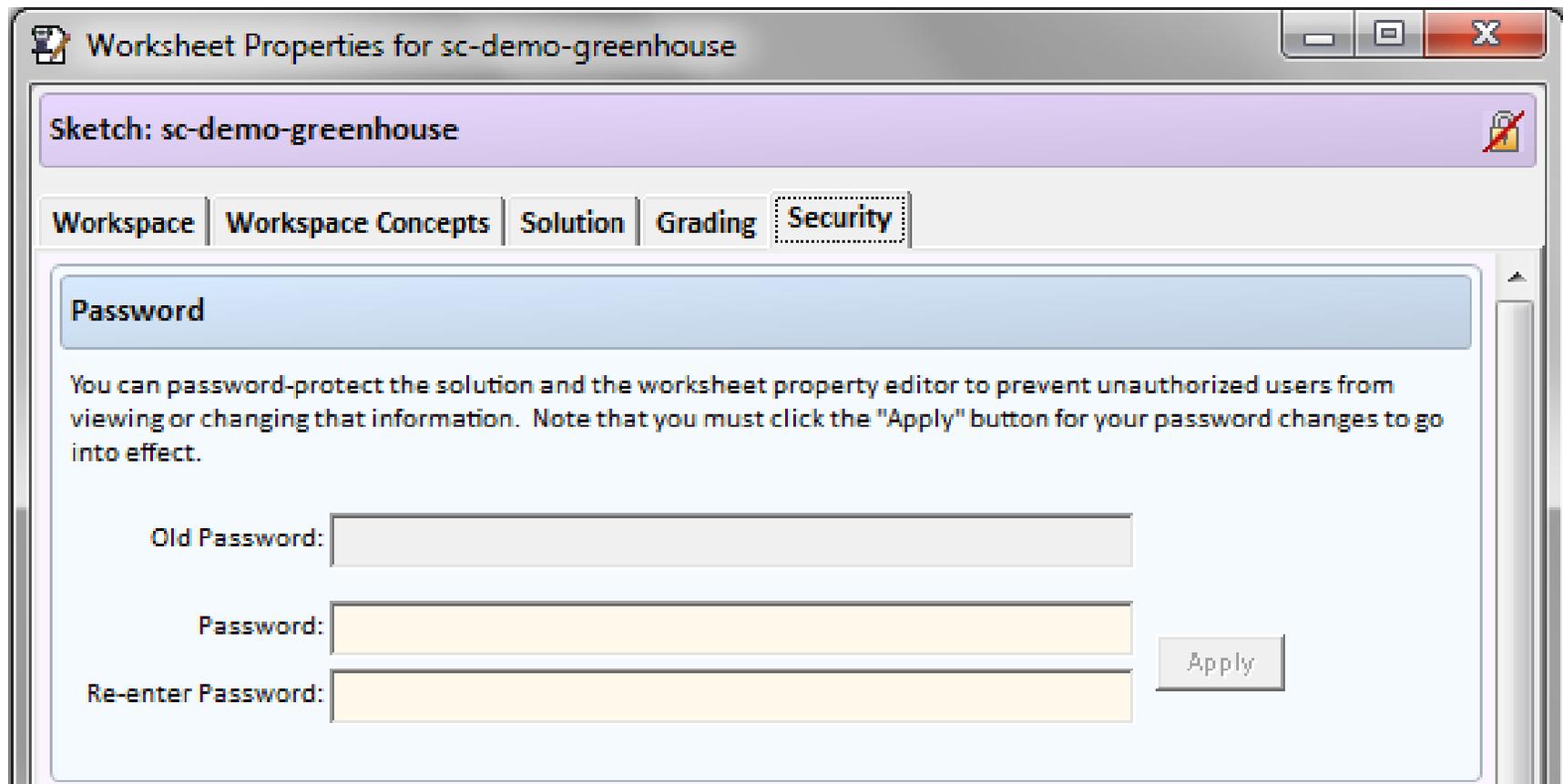
You assign point values to each item

List of items to grade is populated automatically

Points are normalized automatically

Making a New Worksheet: Security

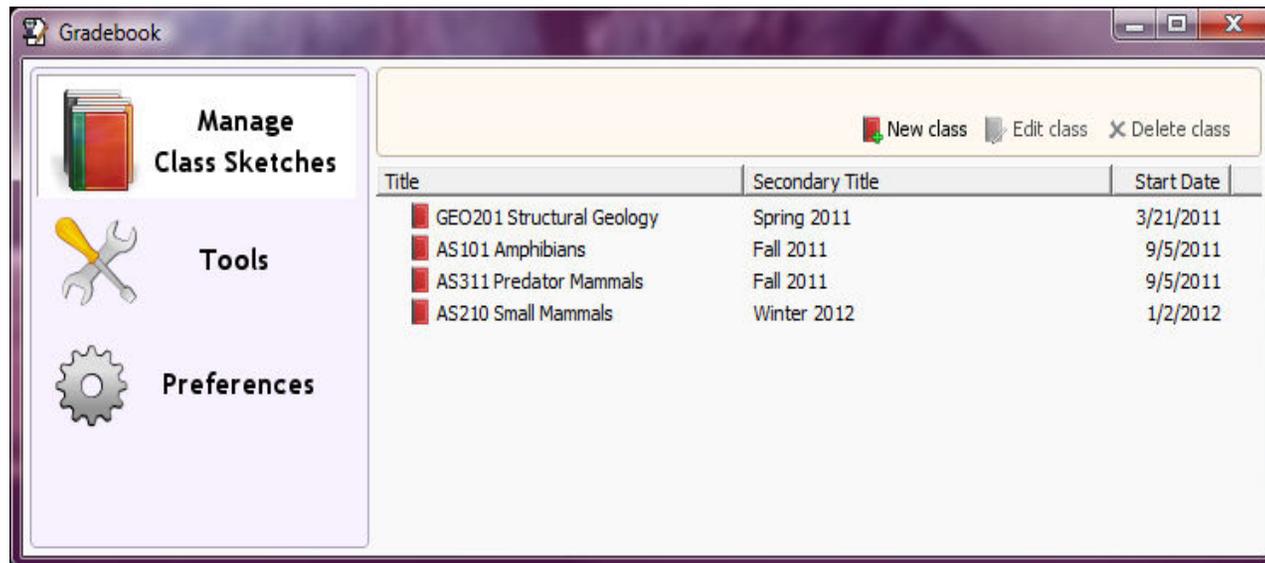
- Add a password to prevent students/subjects from viewing the solution subs sketch and editing the worksheet properties



The screenshot shows a window titled "Worksheet Properties for sc-demo-greenhouse". The window has a title bar with standard minimize, maximize, and close buttons. Below the title bar is a purple header bar with the text "Sketch: sc-demo-greenhouse" and a lock icon on the right. Below the header bar is a tabbed interface with five tabs: "Workspace", "Workspace Concepts", "Solution", "Grading", and "Security". The "Security" tab is selected and highlighted with a dotted border. Below the tabs is a light blue panel with the heading "Password". The panel contains the following text: "You can password-protect the solution and the worksheet property editor to prevent unauthorized users from viewing or changing that information. Note that you must click the 'Apply' button for your password changes to go into effect." Below this text are three input fields: "Old Password:" (a grey field), "Password:" (a yellow field), and "Re-enter Password:" (a yellow field). To the right of these fields is a grey "Apply" button.

CogSketch gradebook

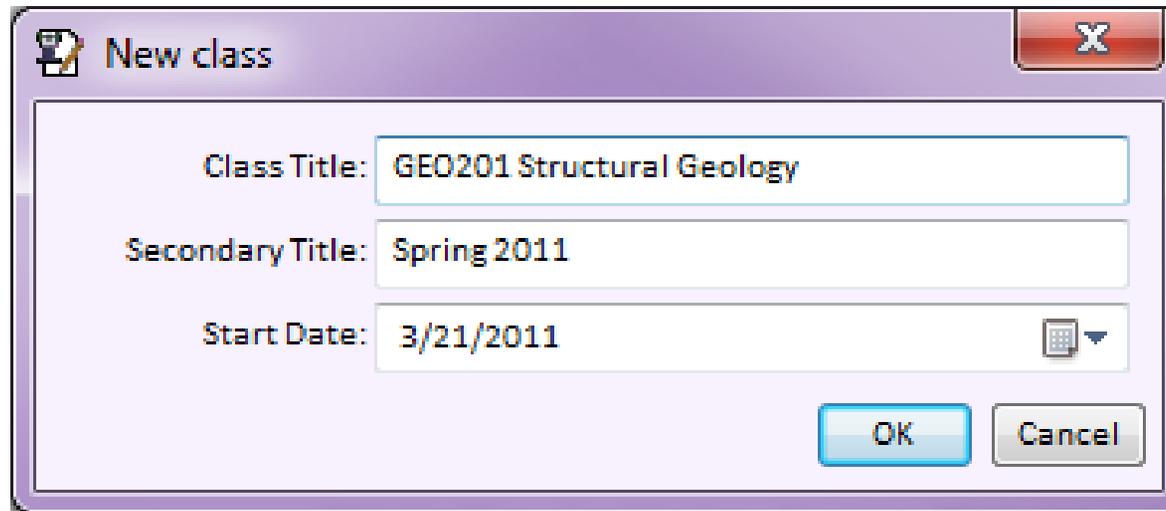
- A tool for organizing and grading sketches submitted by students.



- The gradebook can contain multiple classes, each of which can have multiple assignments.

Gradebook: Adding Classes

- The very first time you open the gradebook, no classes will be defined.
- Click the **New class** button:

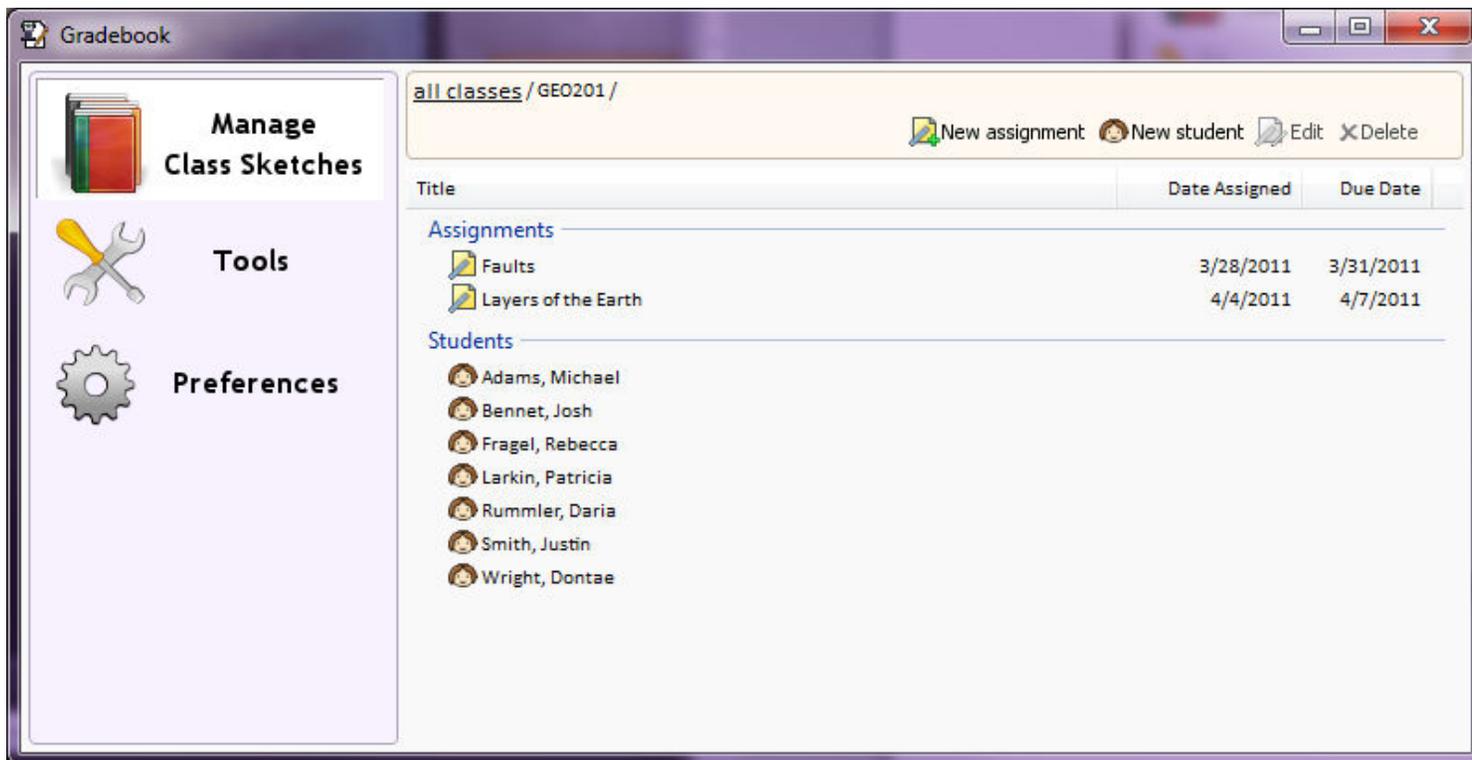


The image shows a dialog box titled "New class" with a close button (X) in the top right corner. The dialog contains three input fields: "Class Title:" with the text "GEO201 Structural Geology", "Secondary Title:" with the text "Spring 2011", and "Start Date:" with the text "3/21/2011" and a calendar icon to its right. At the bottom right of the dialog are two buttons: "OK" and "Cancel".

- The titles can be anything meaningful to you. Here, I've used the secondary title to say that the course happened in the Spring quarter.

Gradebook: Adding assignments and students

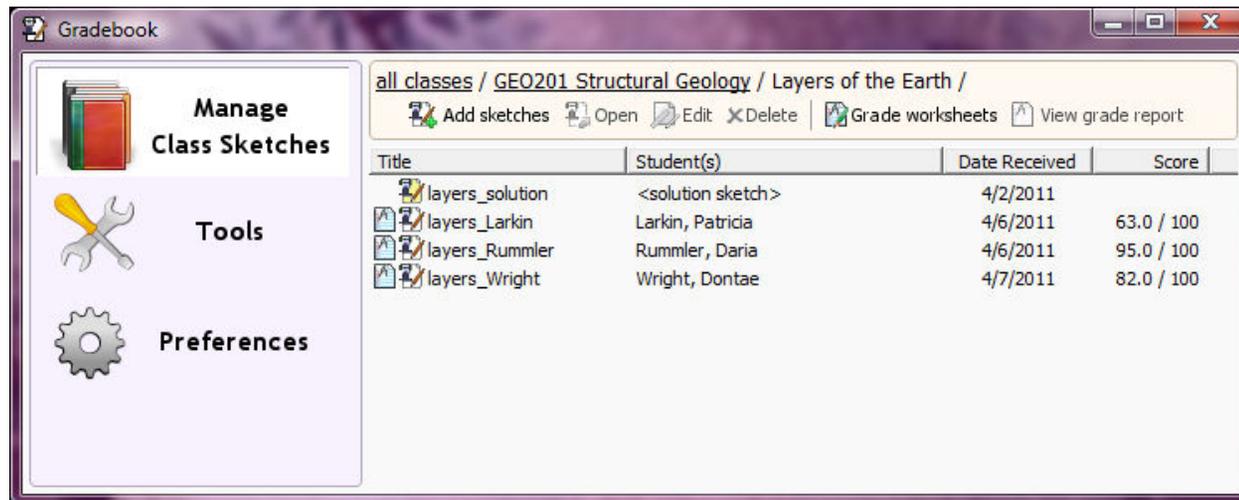
- Double-clicking a class shows the assignments and students for that class:



The **New assignment** and **New student** buttons are used to define assignments and students.

Gradebook: Adding sketches

- Double-clicking an assignment shows the sketches submitted for that assignment:



The screenshot shows the Gradebook application window. The title bar reads "Gradebook". The breadcrumb path is "all classes / GEO201 Structural Geology / Layers of the Earth /". The menu bar includes "Add sketches", "Open", "Edit", "Delete", "Grade worksheets", and "View grade report". The main content area displays a table with the following data:

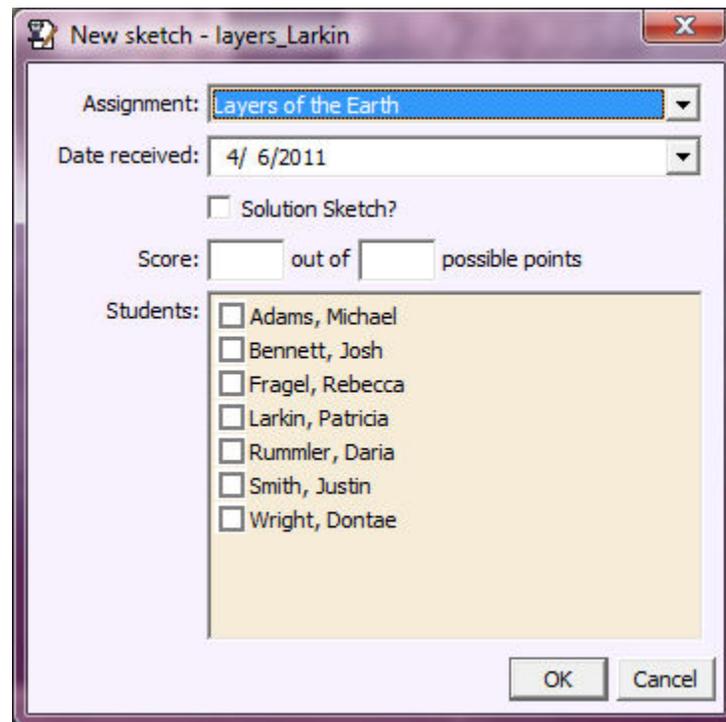
| Title | Student(s) | Date Received | Score |
|-----------------|-------------------|---------------|------------|
| layers_solution | <solution sketch> | 4/2/2011 | |
| layers_Larkin | Larkin, Patricia | 4/6/2011 | 63.0 / 100 |
| layers_Rummler | Rummler, Daria | 4/6/2011 | 95.0 / 100 |
| layers_Wright | Wright, Dontae | 4/7/2011 | 82.0 / 100 |

On the left side of the window, there are three menu items: "Manage Class Sketches" (with a book icon), "Tools" (with a wrench and screwdriver icon), and "Preferences" (with a gear icon).

- Double-clicking a student shows the sketches submitted by that student.

Gradebook: Adding sketches

- There are a couple ways to add sketches:
 - Drag-and-drop
 - **Add sketches** button
- Either way, you'll be prompted for further information:



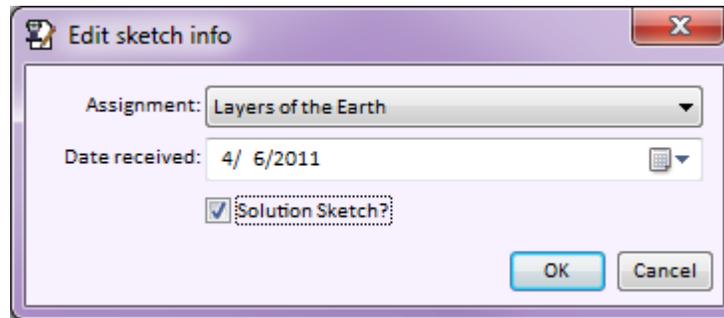
The screenshot shows a dialog box titled "New sketch - layers_Larkin". It contains the following fields and options:

- Assignment:** A dropdown menu with "Layers of the Earth" selected.
- Date received:** A dropdown menu with "4/ 6/2011" selected.
- Solution Sketch?**
- Score:** Two empty text input boxes followed by "out of" and "possible points".
- Students:** A list of names with checkboxes:
 - Adams, Michael
 - Bennett, Josh
 - Fragel, Rebecca
 - Larkin, Patricia
 - Rummler, Daria
 - Smith, Justin
 - Wright, Dontae

At the bottom right, there are "OK" and "Cancel" buttons.

Gradebook: grading

- Worksheets can be graded using our automated grading system.
- One sketch in an assignment must be defined as the solution sketch:

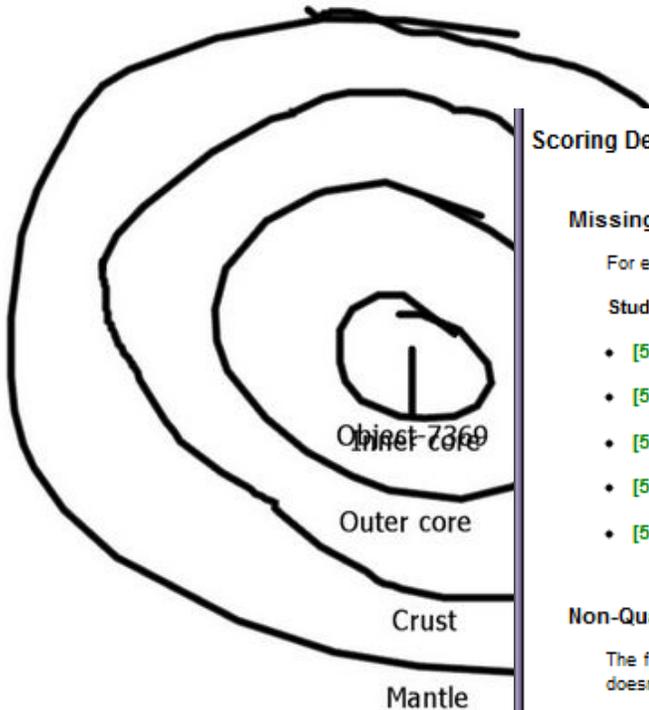


- Grading criteria are used from solution sketch and applied to the students' submitted sketches.
- Click the **Grade worksheets** button and grade reports will be generated for all the selected sketches or all the sketches shown on the screen if none are selected.

Gradebook: example grade report

Grading Report

student: usher
worksheet: layers-1
(D:_temp\grading-test\grades_input\layers-1.sk)



Scoring Details

Missing Glyphs

For each of the glyphs listed below, points are awarded if the student has included the glyph in their sketch.

Student Score: 25 / 25 points

- [5 points] Crust
- [5 points] Inner core
- [5 points] Mantle
- [5 points] Object-7363
- [5 points] Outer core

Non-Quantitative Facts Important for Tutoring

The following are the facts marked as important for tutoring that don't mention quantitative values. Points are awarded if the tutor doesn't find anything wrong with the corresponding facts in the student's sketch.

Student Score: 10 / 30 points

- [10 points]
(objectContains "Outer core" "Inner core")
- [0 points]

Correct Answer would be:
(objectContains "Mantle" "Outer core")

Student had the following similar facts:
(objectContains "Crust" "Outer core")

(objectContains "Inner core" (GlyphFn Object-7369 User-Drawn-Sketch-Layer-688))

Total Score

normalized: 63.0 / 100 points

raw: 51 / 81 points

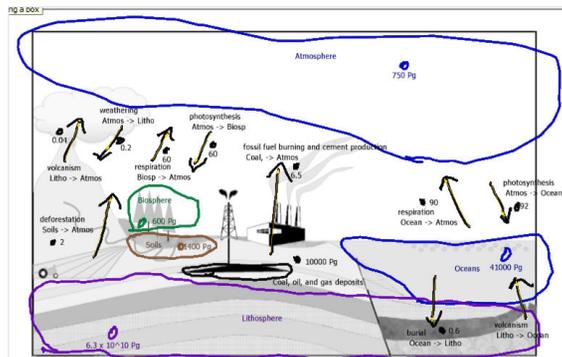
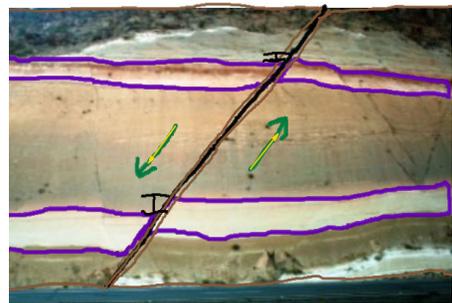
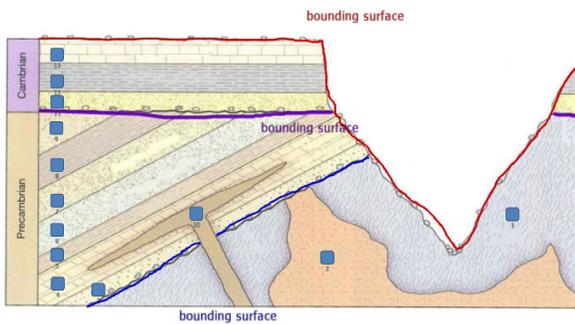
Worksheet Classroom Pilot Studies

- Goal: Formative evaluation
 - Gather data needed to improve representations and algorithms
 - Work out how to make sketch worksheets practical in classrooms and for homework assignments

- First pilot Fall 2009, Brad Sageman's Geo 201: Surface Processes

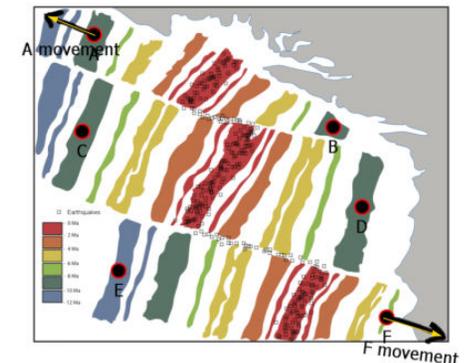
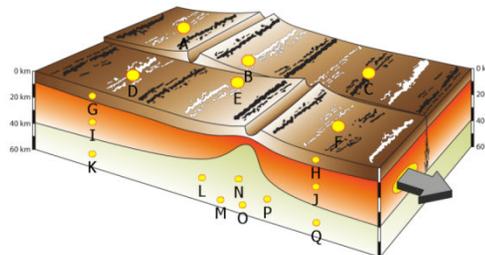
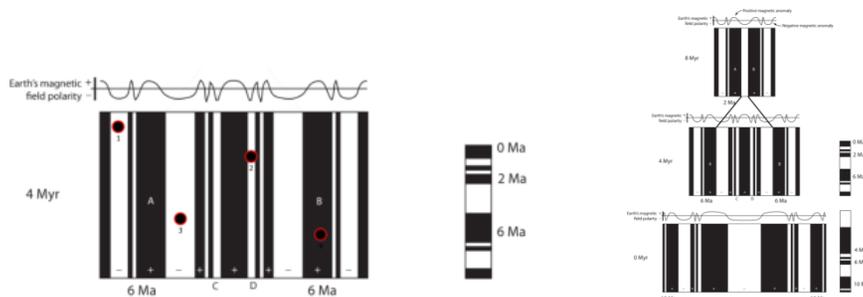
- Round 1: 10 students (out of 28), extra credit

- 3 fault identification, 1 reconstruction of process sequence
- Round 2: Required; carbon cycle: Identify sources, sinks, and flows



Worksheet Classroom Pilots (cont.)

- Earth 201 at NU
 - Earth Systems Revealed (Intro Geology)
 - Prof. Andrew Jacobson
- 4 required worksheet assignments
 - 3 fault identification
 - 1 relative age dating
- 2 extra credit worksheets
 - Carbon cycle
 - Greenhouse effect
- Geology 110 at Carleton College
 - Introductory Geoscience
 - Prof. Sarah Titus
- 4 required worksheet assignments
 - Mid-ocean ridge spreading, illustrating plate tectonics, developed by Basil Tikoff & Maria Chang



Sketching as an Assessment Tool

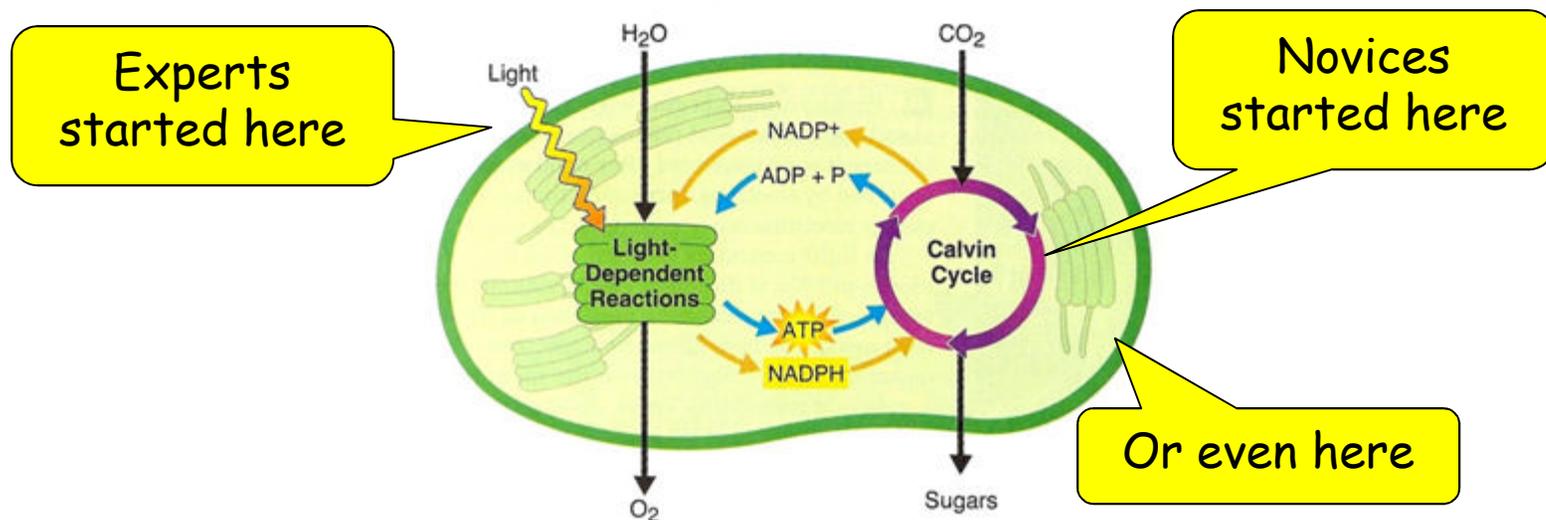
- Can sketching be used to measure student understanding?
 - Evidence so far suggests yes, as discussed next
 - But more research is needed
- Implications
 - Potentially can be used to assess student understanding
 - Sketch-based intelligent tutors can use assessments to better guide students

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

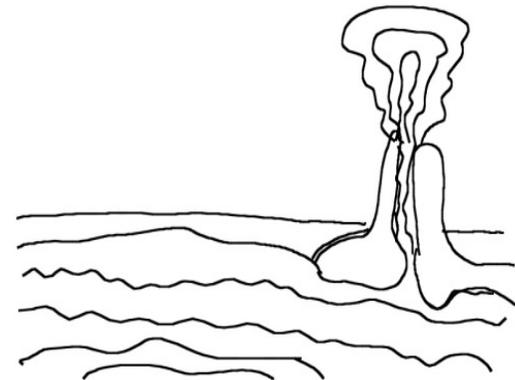
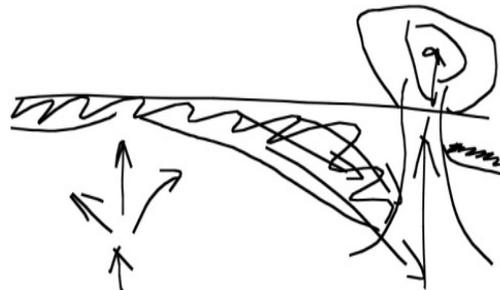
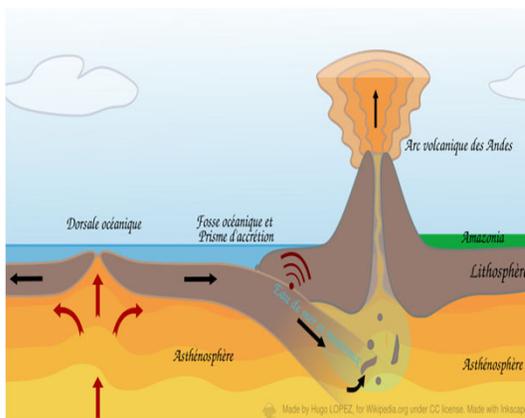
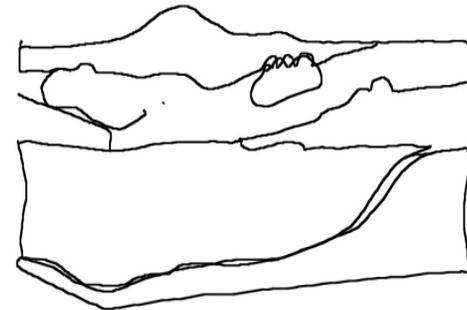
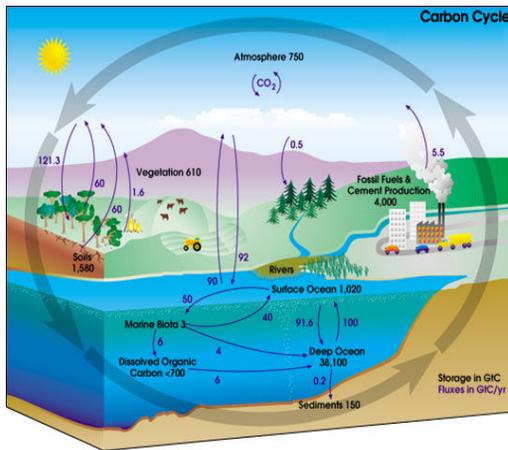
Geo students include more relations

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



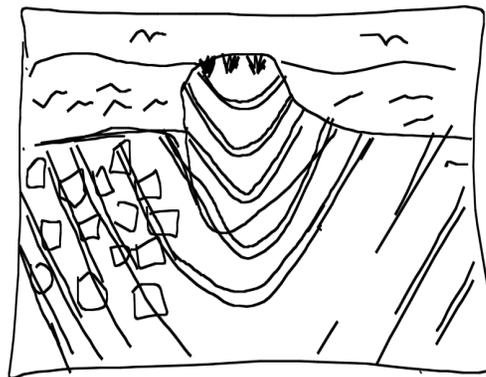
No differences for Control sketch

Geo students include more key structures

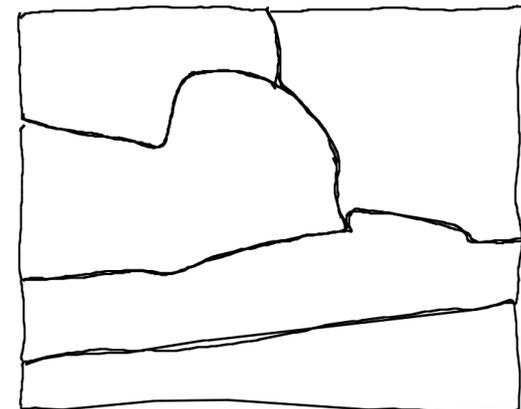
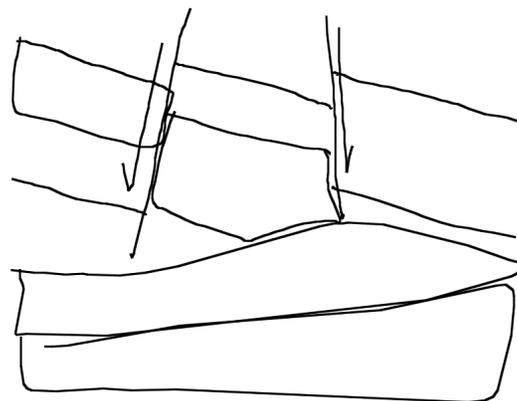
Geo formation (key structures shown)



Geo student sketch



Novice sketch



No differences for Control sketches

Summary of results

For causal diagrams:

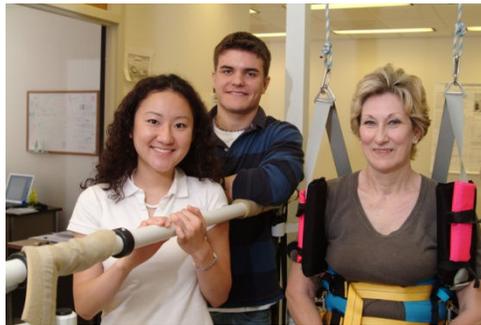
- Geoscience students include more causal knowledge, relative to novices
 - They focus more on depicting relational information and less on depicting the objects present
 - They begin their sketches with causal/relational information more often than novices

For photos of geological formations:

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

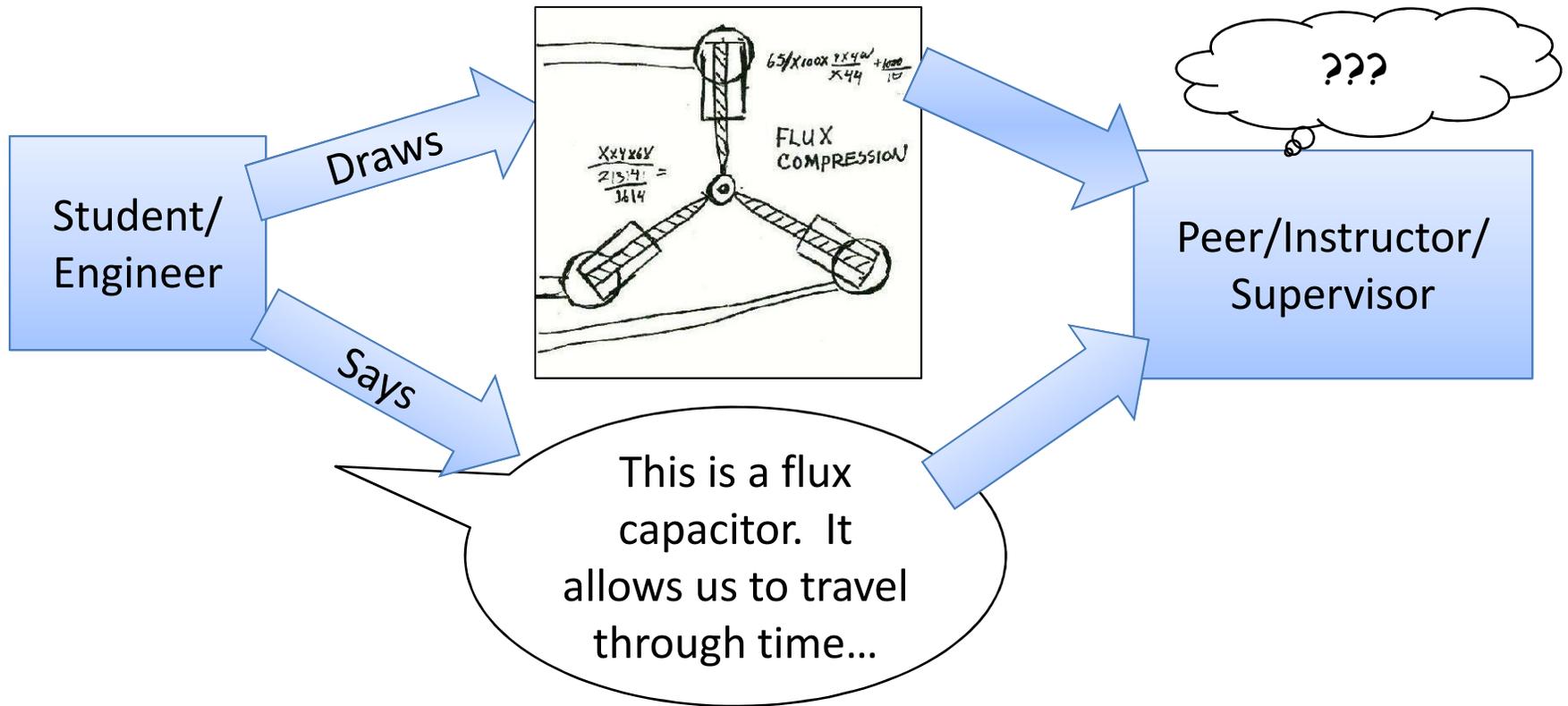
Design Coach: Setting and Problem

Engineering Design and Communication Course (EDC)
at Northwestern University



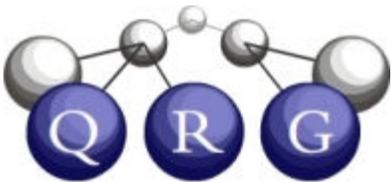
Problem:
Students have trouble using
sketches to communicate

Explaining Designs with Sketches

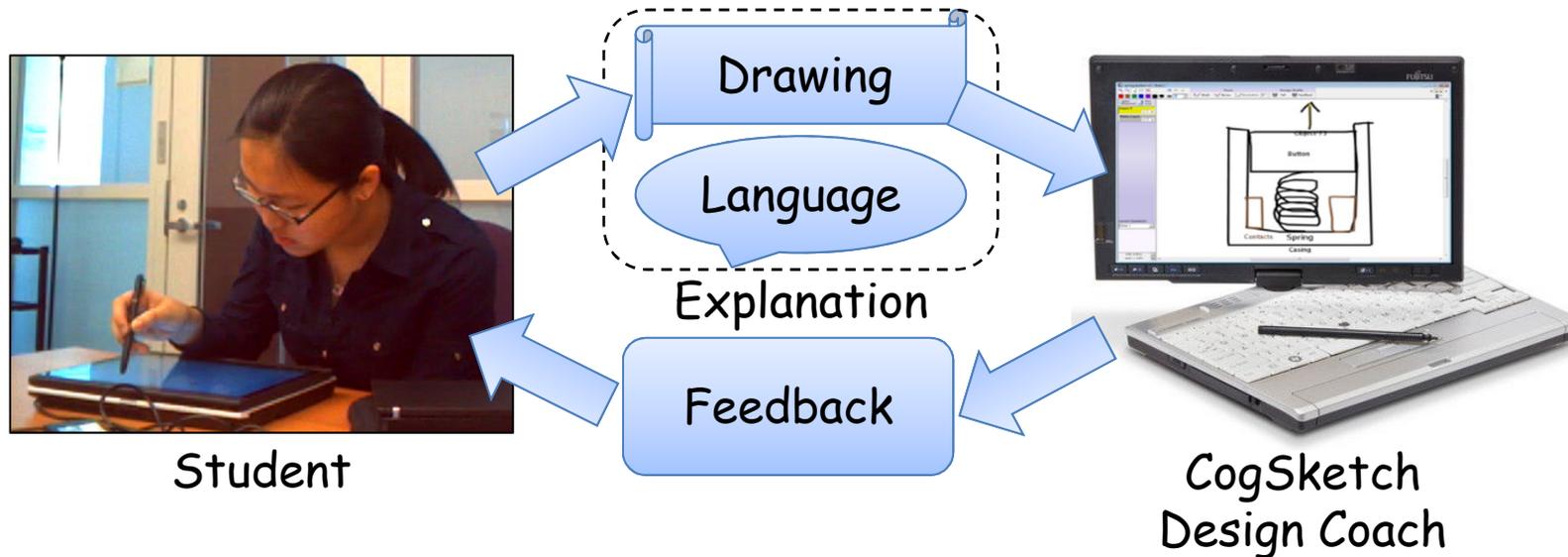


Early design explanations:

- Sketches are roughly drawn and ambiguous
- Language clarifies drawing and adds teleological information

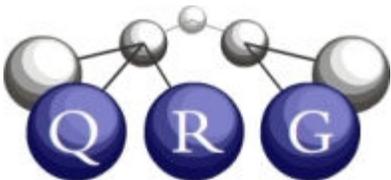


Design Coach



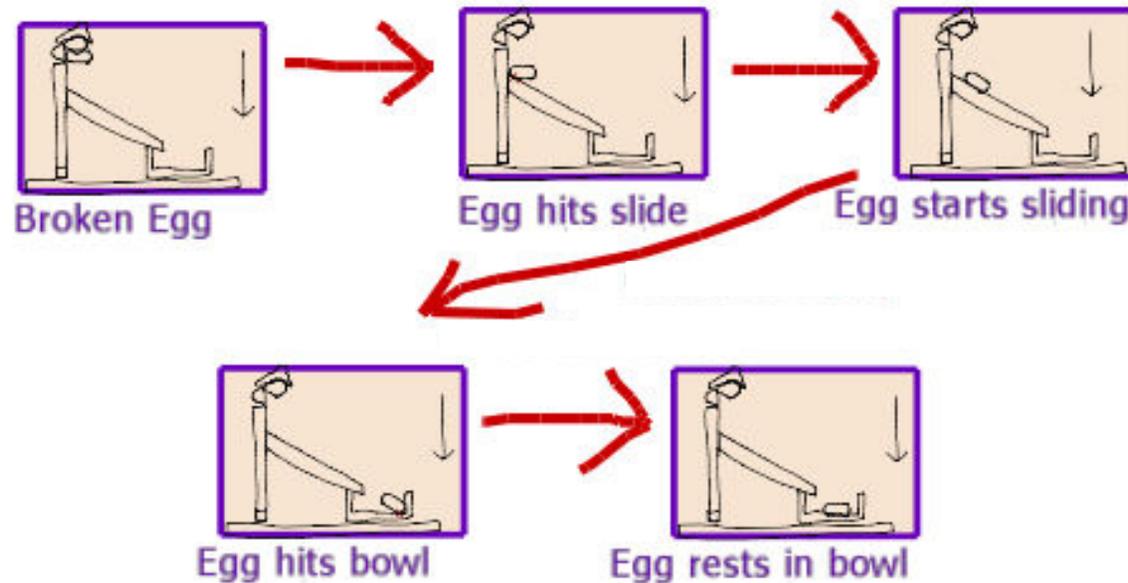
Like human-to-human sketching:

- Student supplements sketch with language
- Qualitative reasoning allows coach to understand mechanisms
- Coach provides feedback when explanation is unclear



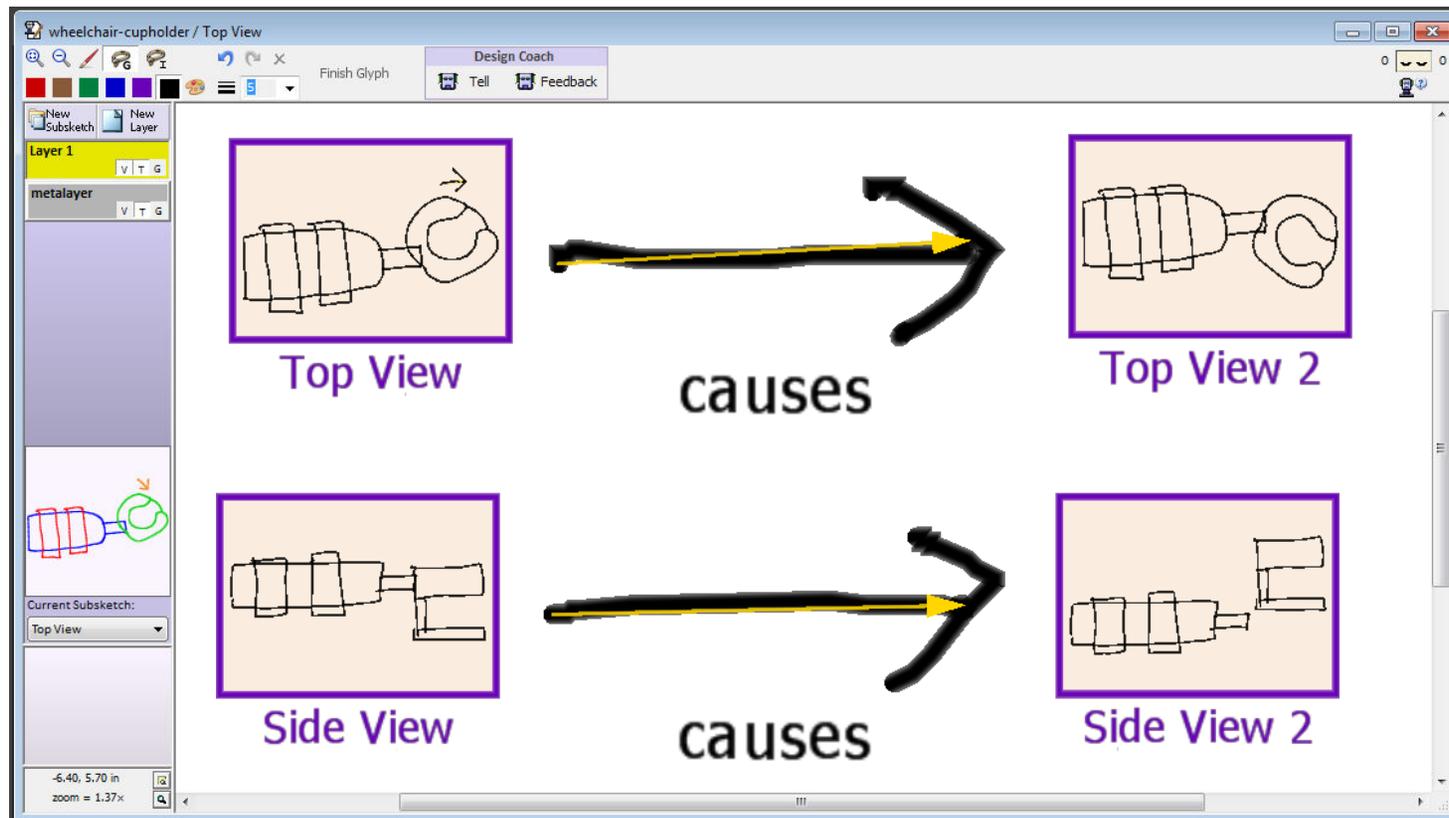
Students Create Multiple Sketches

- Multiple sketches depict the design in different operating states
- User draws arrows between these states, forming a comic graph



Students Create Multiple Sketches

- Multiple sketches depict the design in different operating states
- User draws arrows between these states, forming a comic graph

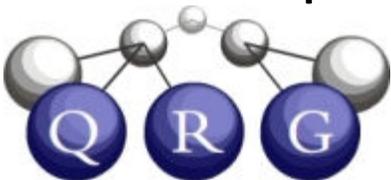


Students Add Sentences

- Template-based entry of sentences
- Subject-Verb-Object form, may be compound

The screenshot displays a user interface for adding sentences. It features two rows of input fields, each with a set of navigation controls (back, forward, up, down, and a play button) on the left. The first row shows a simple sentence: "In Top View ... Cup Holder rotates clockwise". Below this row, four purple callout boxes identify the components: "context" (Top View), "subject" (Cup Holder), "verb" (rotates), and "object" (clockwise). The second row shows a compound sentence: "In Top View ... Cup Holder is being forced up which causes Cup Holder moves up". A large purple callout box labeled "compound sentence" points to the entire second row.

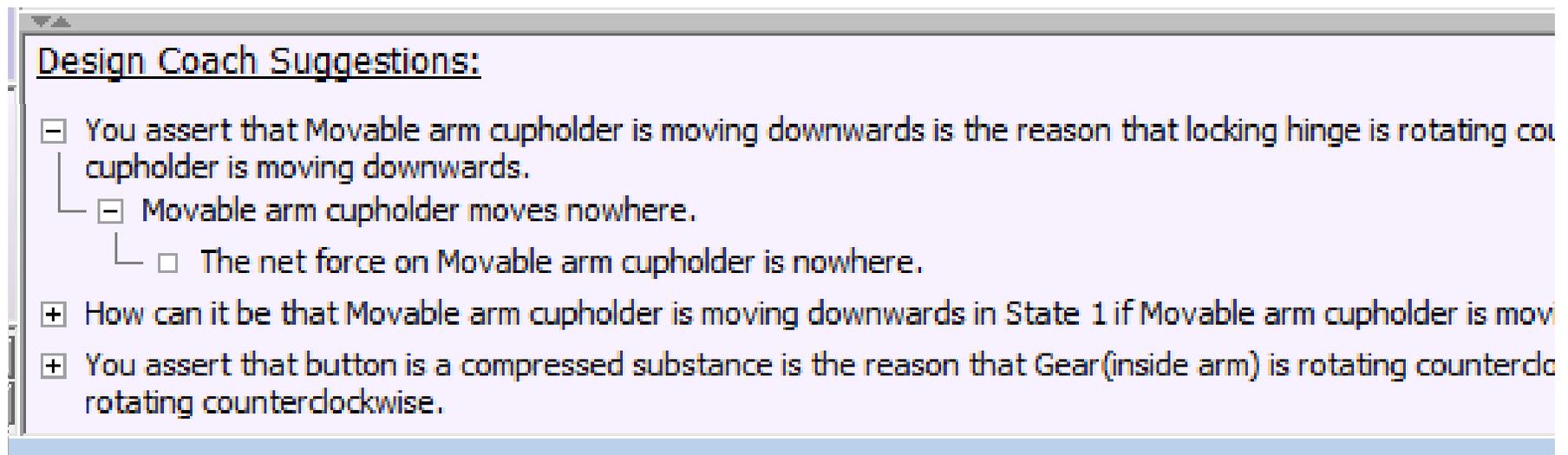
- Generates facts which use the same knowledge representations as in the sketch



Generating Feedback for Students

Design Coach checks for:

1. Unexplained or impossible motions depicted in the sketch [Wetzel & Forbus, 2008]
2. Unsupported or contradictory template-based sentences [Wetzel & Forbus, 2009]
3. User input errors

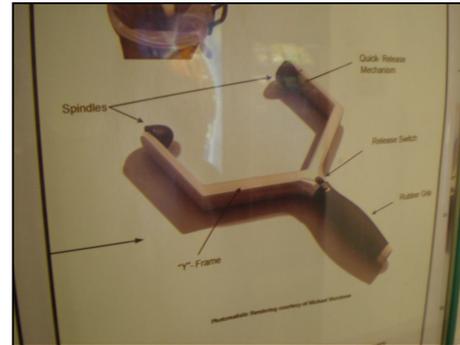
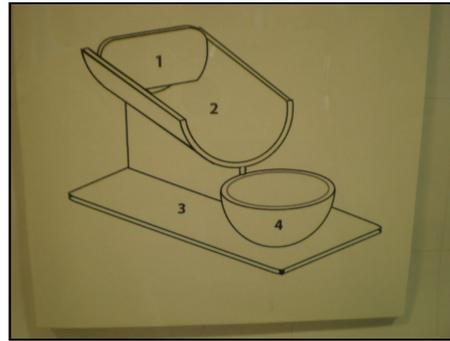


The image shows a screenshot of a software window titled "Design Coach Suggestions:". The window has a light purple background and a grey border. It contains a list of suggestions with checkboxes and expandable/collapsible icons. The suggestions are:

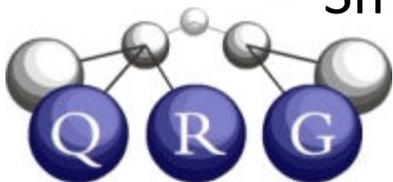
- You assert that Movable arm cupholder is moving downwards is the reason that locking hinge is rotating clockwise. cupholder is moving downwards.
 - Movable arm cupholder moves nowhere.
 - The net force on Movable arm cupholder is nowhere.
- How can it be that Movable arm cupholder is moving downwards in State 1 if Movable arm cupholder is moving upwards?
- You assert that button is a compressed substance is the reason that Gear (inside arm) is rotating counterclockwise. Gear (inside arm) is rotating clockwise.

Design Coach Classroom Progress

- 2009-2010
 - Tested coverage on past design projects
 - Understood 16 out of 39 projects (20 were in our domain, mechanics)
 - See Wetzel & Forbus, IAAI09

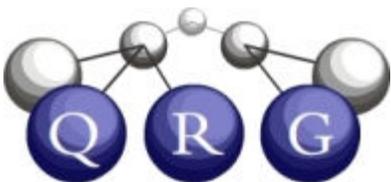
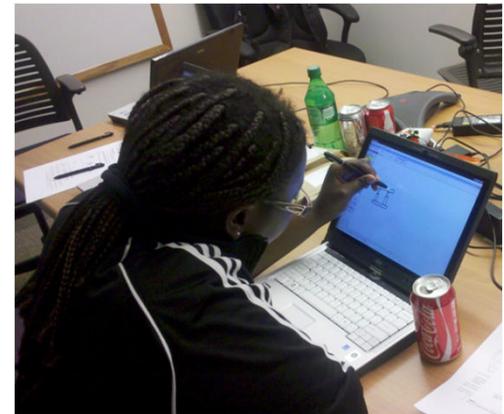


- 2010-2011
 - Pull out studies using optional homework assignment
 - Small sample size



Design Coach Classroom Progress

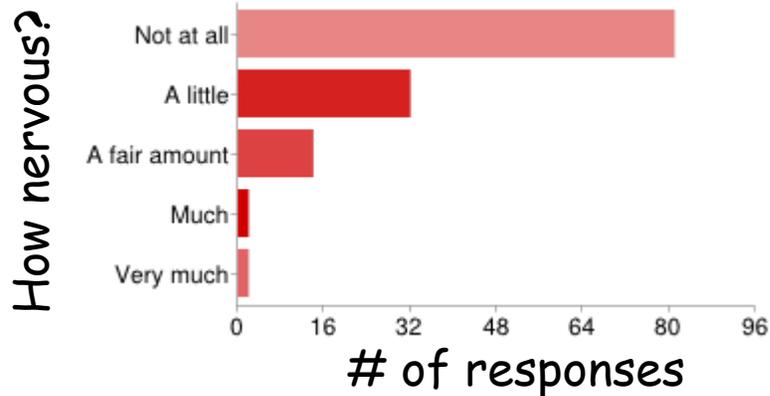
- 2011-2012
 - Used as a mandatory homework assignment in one section in Fall, two in Winter (EDC has 16 students per section)
 - Collected 88 explanations altogether
 - Using these to further improve the coach
 - Added teleological language
 - Functions and ways of achieving them
 - Students explain and get feedback on the purposes of their design
 - Surveys on sketching anxiety were offered before and after activity



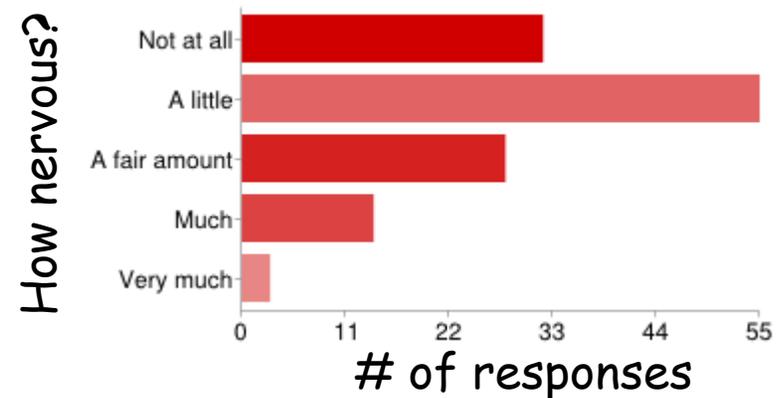
Sketching Anxiety Survey

- Based on math anxiety survey by Beilock et al (2010)
- Students begin more nervous about sketching in engineering context:

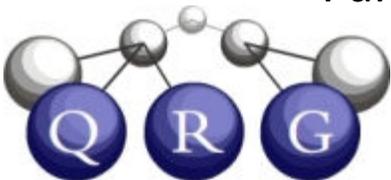
Sketching for fun at a party with friends



Sketching an engineering design

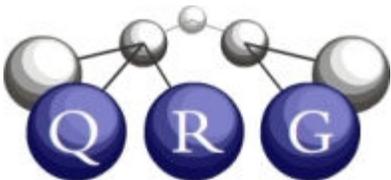


- Analysis of pre- and post- indicated possible effect of CogSketch Design Coach assignment on anxiety and skill
 - Further research required to confirm and explain



Current Design Coach Capabilities

- Focused on mechanical designs
 - Supports forces, motion, springs, and gears
- Teleological vocabulary includes:
 - Increasing comfort
 - Containing/holding
 - Adapting to variable size
 - Attaching/detaching
- Teleology will be extended over time to cover engineering project domains



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 Coach is a test of this hypothesis, underway

