Mining a Collection of Animated Sketches

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How can we make a set of digital assets useful for teaching and research? As we amass data, it is crucial to select and interpret what is presented. This paper describes how a collection of animated drawings has been made accessible through an iterative development process. It describes a Web matrix interface, interpreted lesson formats and an assessment method.
The assessment method of tallying achievement on design criteria before a lesson reveals inherent challenges of the problem, tallying afterwards reveals the effectiveness of the lesson in addressing those challenges. Using space-planning layout problems, we found that students readily picked up simple graphic devices such as measurement grids, adjacency diagrams and thumbnail sketches. Students showed less immediate improvement on skills that require juggling of multiple criteria, such as meeting all programmed area size requirements.

Keywords*: Sketching; design process; architectural education; animation; instruction.*

I. Introduction

When developing design concepts, a designer sketches to externalize mental images. The designer alternates mark-making with moments of reflection, gradually creating a graphic record of the process. By recording the sequential layering of marks and playing them back as animations, we can reveal the thinking process hidden within drawings. The Digital Sketching Project (Cheng 2004) has generated a collection of digital sketches by professionals, teachers and students. We looked at the questions of what these sketches could reveal and how to make them useful.

II. Related work in pen-and-paper input and instructional animations

The project uses the Logitech Io version of the Anoto pen-and-paper technology. As a person draws or writes, the pen's embedded camera records its location on specially patterned paper. When the pen is placed in a USB dock, stored time-stamped strokes are transferred; Bluetooth versions of the pen can transmit images wirelessly. Developers are engaged in looking at how this system can be combined with other relevant media into an accessible interface. The Explanograms project (Pears 2004) put computer science tutor notes online as Java animations along

with audio notes. PapierCraft (Liao and Guimbretière 2005) combines handwritten sketches or notes with photos and includes pen gesture input. Butterfly-Net (Yeh & Klemmer 2005) looks at how scientists can combine sketches, notes photos, and physical samples in a multimedia browser. The Ideas project facilitates design collaboration by publishing static personal notes to a shared calendar-based blog or a data wall.

The pen is a natural extension to other stylus-based tools. Paper CP uses the Anoto system as an alternative to Tablet PC's for giving anonymous live Classroom Presenter feedback. SketchBuilder (Smithnosky 2005) links up Logitech Io2 pen input to a sketch recognition and mechanical engineering simulation software. It also supports animated annotations on a partner's sketch.

Our project takes a narrower domain and looks at how to format and present animations for effective understanding. Research on instructional animation shows that effectiveness is highly dependent on the content, audience and delivery mechanism. The density of animations can produce cognitive overload, so still images can be equally effective as animation for learning (Tversky & Morrison 2002) and schematic representations can be more effective than realistic ones (Scheiter and Gerjets 2007). Allowing users to select the animation's speed or to click through a short segments gives control over the flow of information. Moghaddam and Moballeghi (2006) emphasize the elimination of distractions such as colors, shapes or sounds in guidelines for effective animations.

## III. Web interface for accessing drawings

We put our collection of sketch animations online to share the process of developing ideas through sketching. As soon as a sketch is drawn with a digital pen-and-paper system, the sketch file can be uploaded to our server, where PHP Web-scripting language automatically translates it for the Web and adds it to a matrix of images linked to animated sketches.

This allows a viewer to browse through an expanding collection of sketches and upload new additions. A large number of students can use the digital pens in class, and then immediately share the results on the Web. Each browseable directory shows different approaches to the same sketching task, including mental maps, design tasks, drawing from observation and analytic diagramming. Examining how non-designers, design students and design professionals approach the same problem can illuminate how expertise develops.

To create this webpage, the team translated Logitech IoReader 1.0's XML .PEN format into Adobe's Scaleable Vector Graphics (SVG) format. While the Logitech format lets us use an interactive slider bar to closely examine a drawing, the auto-play SVG format allows us to see the actual pace of the stroke timing and share the drawings with the cross-platform Mozilla Firefox browser. One student explained why it is useful to see the stroke timing, "Presenting sketches in animation shows especially where the designer had to pause, or got stuck. This could alert someone to places where elements of the design might disconnect – could either be great, like a leap of imagination, or bad, as in parts not working together well." For longevity, we are translating files to the Flash SWF format.

Animations introduce the element of time into viewing a drawing, and we can manipulate this aspect to see more into a drawing. To examine different aspects of the drawing, we can choose to play the scripts at different speeds. We sometimes need to browse through complex layered drawings quickly and see simpler drawings more slowly. To see the steps of the drawings with even more clarity, we can isolate sections by color according to the pauses in the drawing sequence. A recent modification to the script draws each time-clustered set initially as a sequence of red strokes. As the set is completed, the strokes turn black. After a pause, the next set of strokes is drawn in red. We can optionally break stroke clusters into separate files for annotated lessons. We can also choose to sequentially draw the

Figure 1
Gallery allows browsing of nested directories, automatically processing uploaded drawings to enlarge the matrix.
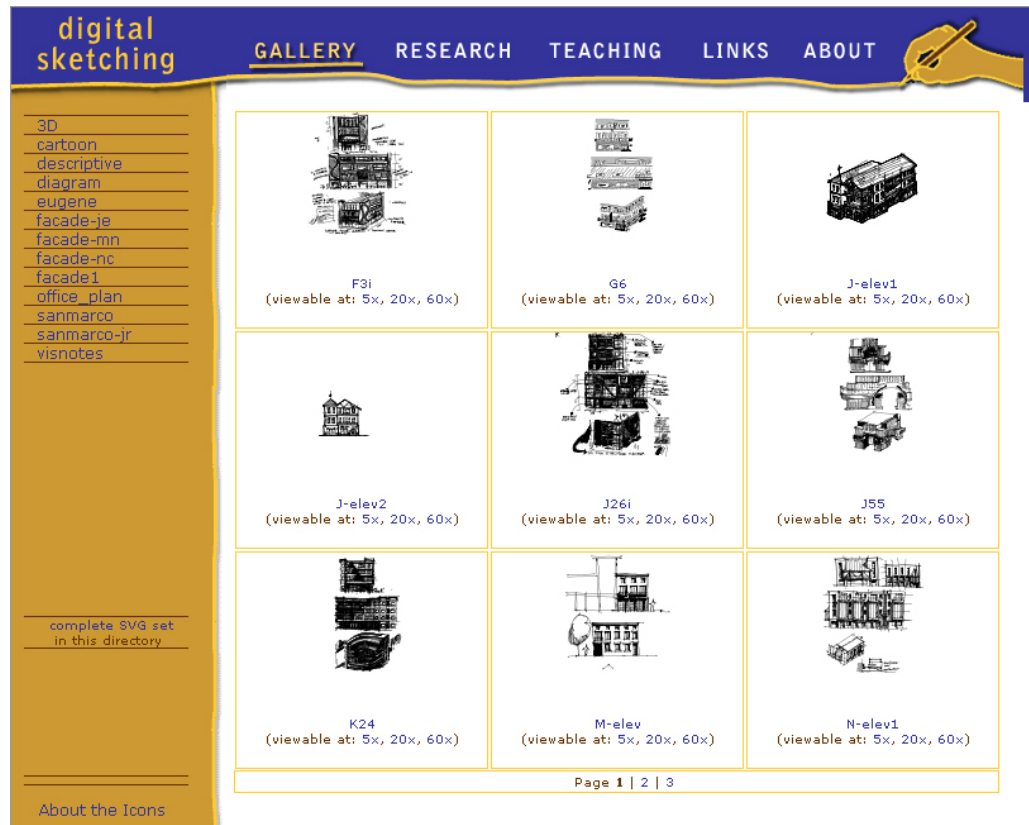
stroke's component vectors so that the direction of the line is revealed.

More generally, a key to useful representations is examining how the basic data of the drawings can be manipulated to reveal more information. By considering the intrinsic nature of drawing as actions punctuated by thinking pauses, we could accentuate the pauses and annotate the actions.

IV. Lessons

Comparing interactive animations and storyboards (Cheng 2006) confirmed the instructional literature that beginners can become confused by a series of undifferentiated strokes. Pauses help break up the stream of strokes into cognitive chunks. Distinct named steps provide a scaffold for comprehending the chunks. With this in mind, we have created annotated lessons for beginning students in the first or second year of architecture school. Below we describe four ways to present the lessons, with an analysis of strengths, weaknesses & possibilities that come from querying students and colleagues.

1. Multiple animated examples of one technique
2. Designer's narration of the sketch
3. Slideshow with questions
4. Researcher's interpretation interspersed with exercises

1. Multiple examples on one page.

To navigate through the spectrum of solutions, we can highlight exemplars of each method and provide guidance for comparing the methods with questions and annotations. Students can select the ones they find that are interesting and switch between them.

While this format doesn't add much interpretation, it can stimulate discussion without much authoring work. It is easy to select a meaningful set of examples, write an introduction and relevant questions. We can link these pages to a wiki so that the images could be optionally enriched by multiple critical viewpoints.

2. Designer's audio narration of the sketch

We captured the video screen and audio narrative of experienced designers interactively reviewing their drawings with the Logitech IoReader. Indexing the narrative segments with titles gives an intelligible summary of the process. A paraphrased text transcript allows quick browsing for those who don't want audio. We used Camtasia Studio software for

video-capture and Adobe Captivate for authoring the interactive lesson.

In reviewing the lesson, we found that the actual author's voice has a compelling authenticity. But the unrehearsed description was too long and diffuse for continuous viewing. Selected highlights of the author's story combined with commentary in other voices with would make the lesson more interesting.

3. Slideshow with question

How can we engage the students to care about what they are seeing? Though posing questions, we can put a student into the position of the designer and lead them through the sequence of decisions in a design process. For each step of the slideshow example, we start by asking a leading question. The question is followed by a slide displaying the drawing marks made to address the question, along with short text explanations of basic relevant vocabulary terms. In the future, we can link vocabulary terms to illustrative examples, giving context through cross-referencing. For example, we can show how a designer takes a diagrammatic space plan and elaborates it to define architectural elements: single-line divisions between spaces become double lines, windows and doors are added, then the wall thicknesses are hatched. For the prototype, we created an Adobe

Figure 2
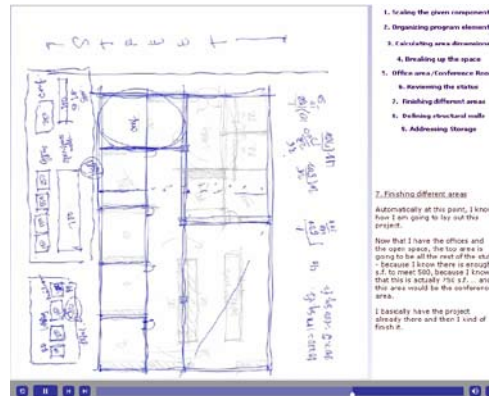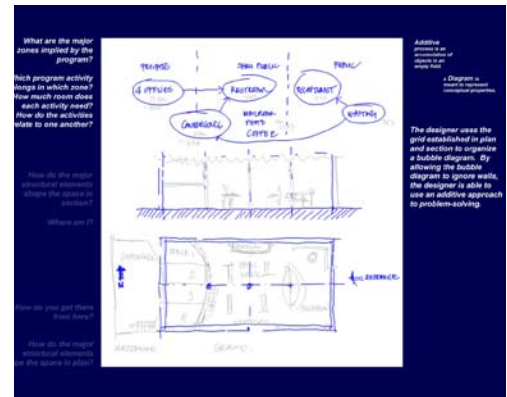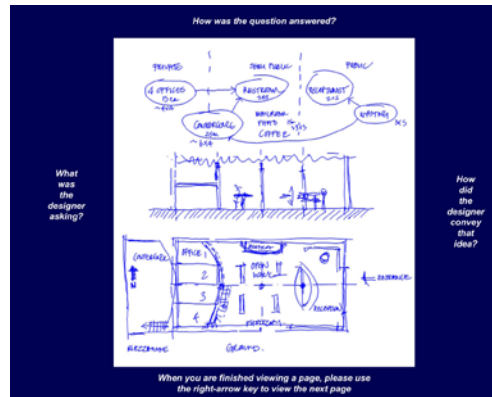*A brief guide to strong examples provides an entry point into the collection.*

Figure 3
The designer tells about his design process in a segmented video with audio narration.

PDF file, allowing users to page back and forth between the slides.

While the questions lead the viewers into the problem and organized the sketch information into steps, there was an issue of passivity. The slideshow didn't ask the students to create something (i.e. apply the step in practice). It did not test their comprehension or ability. So we guessed that students might be more engaged if segments of the presentation were interspersed with active exercises related to the illustrated step.

4. Researcher's interpretation interspersed with exercises

From the previous lessons, we alternated drawing explanation with drawing exercise. Each explanation video segment combines text and audio reading of the text with an autoplay animation. As each one – to three-minute segment ends, students are cued to try an associated drawing exercise. After trying the exercise, they can view an animated solution. Experts can skip the exercise and browse through the explanation at two different speeds. They can click through the numbered video segments and either listen to the explanation OR browse the text.

Being able to choose between short segments of video and drawing exercises makes the lesson more interesting. The exercises need to be further tested to tune the level of difficulty and to verify their relevance to the example. Adding audio narration to the exercises would provide a more consistent experience.

In reviewing the lessons, we realize that one format doesn't fit all. Because people are able to process different amounts and kinds of information, we need to provide options. Advanced designers or researchers seek a detailed, sophisticated explanation; beginners need this complexity filtered and vocabulary explained. One student suggested combining the formats to create a more effective lesson. A quick autoplay overview animation could be followed by clicking through interpreted audio/text steps with optional drawing activities. For further development, we needed to understand where the lessons were effective and what aspects needed better instruction.

V. Evaluation methodology

We evaluated the effectiveness of the digital sketch lessons by comparing student performance before and after studying a set of them. This follows an earlier study comparing student performance after studying two different kinds of examples (Cheng 2006). 22 intermediate-level architecture students did a pre-test of designing a graphic design office in an existing building shell, then studied digital
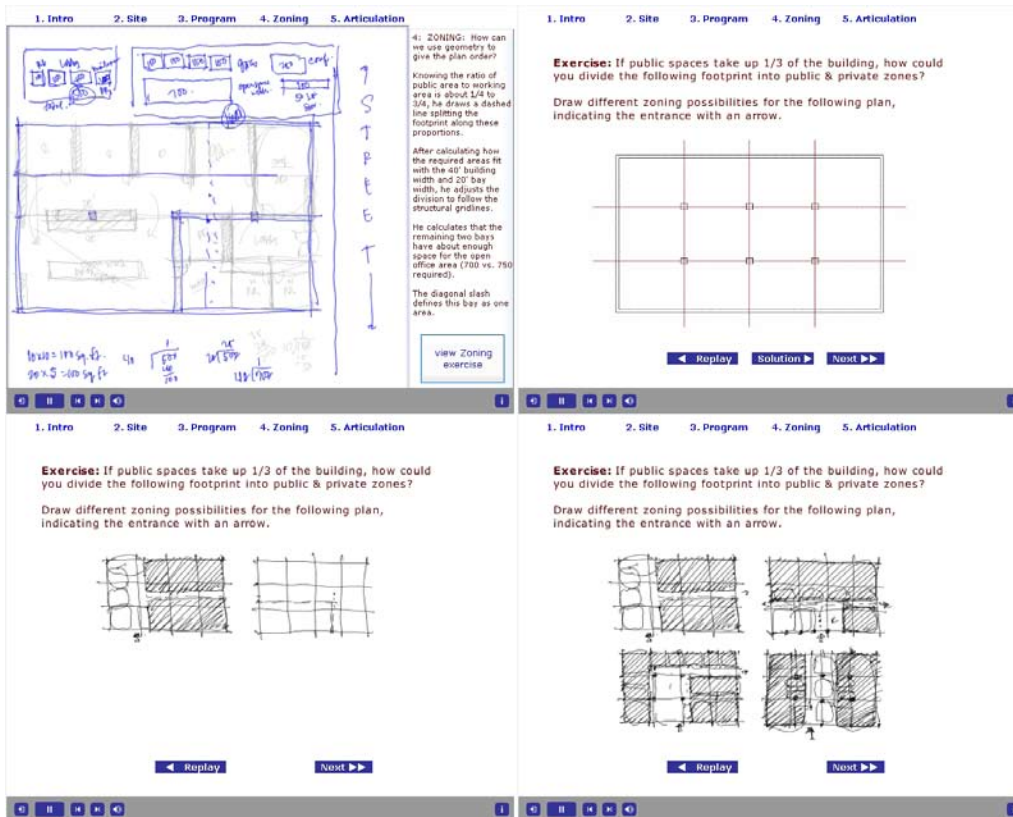
sketches as IoReader interactive animations, online SVG autoplay animations, and annotated slideshows. Students could freely examine examples at their own pace. Afterwards, 19 students from the class tried a similar post-test, designing a rock gym for an existing building envelope. By tallying student performance on spatial organization and use of graphic conventions, scale and proportions, we could identify where the examples were the most helpful.

We examined the consistency of the data by comparing the student tallies against a larger inclusive post-test pool of 81 rock-gym samples that includes different student abilities and teaching co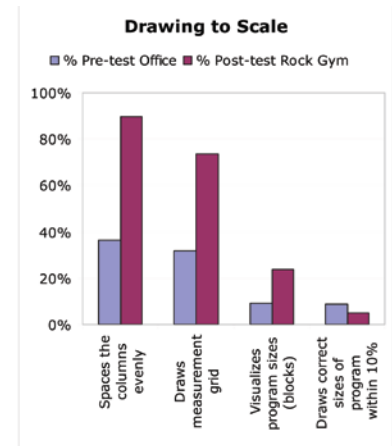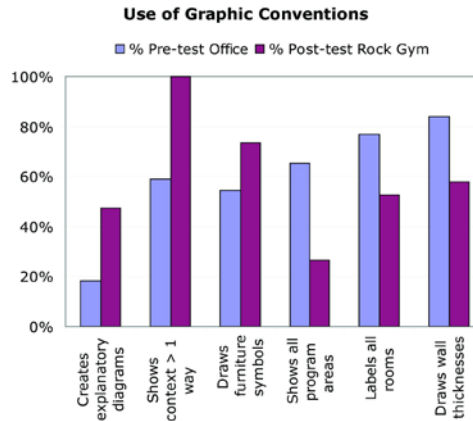ntexts. We discuss items whose post-test averages match the larger pool and show a strong pre-test and post-test difference. The results are preliminary because we still need to find out how much of the performance difference is due to the sequence of the problems and the difference between the two problems. To clarify the differences between the two exercises, we need to compare our results with a control situation of no lesson in between the pre-test and post test OR by reversing the order of the exercises.

Data

After studying examples, the students demonstrated some graphic skills that were uncommon in the pre-test group. Several students said it was unexpected

Use of Graphic Conventions

■ % Pre-test Office ■ % Post-test Rock Gym

Drawing to Scale

■ % Pre-test Office ■ % Post-test Rock Gym

how often experienced designers used bubble diagrams to organize program relationships. Once they saw their value in the examples, they emulated the operation. Only 18% of the pre-test students created bubble diagrams, whereas 34% more used bubble diagrams to organize spatial relationships and 29% more created explanatory diagrams for the post-test. These skills were not difficult, but it just didn't occur to the students to include them.

In drawing the existing building context, a great number of students adopted drawing a structural grid (42%) and naturally more were able to space the columns evenly from the building perimeter (53%). 41% more showed clues to the building context in at least two ways; adding a north arrow, street or parking indicators, or a sun symbol.

The more difficult nature of the 2nd problem, a rock gym requiring 3D arrangement of an additional mezzanine floor, shaped the difference in results. Most likely because of the spatial complexity of the problem, 38% more students drew an elevation or section. The vertical nature of the problem reduced the need for horizontal circulation, making it easier for the hallway circulation to take up less than one-fifth (20%) of the floor plan. The 36% increase in creating efficient circulation could also be attributed to

the greater experience in doing the second problem. 22% fewer students transformed their plans, 13% fewer used zoning or modules to organize the plan, perhaps because it was not only a single floor.

Negative performance differences can be attributed to the greater difficulty of the second problem. While +15% more visualized program areas sizes with scaled rectangles or calculations, more missed required program areas (-39%) in the more complicated second problem. Both problems listed 11 spaces; the first duplicated 4 private offices while the second only duplicated a pair of locker rooms, requiring effectively 8 vs. 10 types of spaces. Students became more lax on using double lines (-26%) and labeling the spaces (-33%) on the second problem, probably because they ran out of time.

Complexity makes it challenging for beginners to use planning skills. While they created geometric zones for a one-story pre-test, when faced with the three-dimensional post-test rock gym, fewer students used geometric zones or modules for planning.

Evaluation analysis
What did the students learn from the lessons? After seeing the sketches, one student was able to
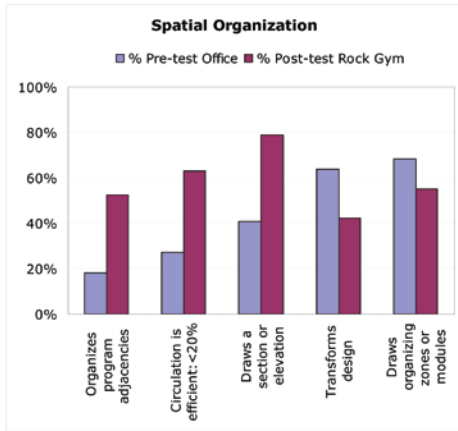
Spatial Organization

■ % Pre-test Office ■ % Post-test Rock Gym

articulate the power of sketches: "Sketches allow the designer to move ideas from the brain to the paper and to the eye. That is, sketching out a space helps the designer make judgments on size and relation because the designer can look at the elements more objectively. The sketches also help the designer get a design on paper so other designs can be generated without forgetting the first idea. The paper trail allows the designer to have a toolbox of ideas to draw from."

While students may have read about drawing techniques previously, they get a vivid reminder of how to use particular techniques in context by watching the animations. For example, experienced designers know how to use different views to reveal what's missing. Many beginners did not draw a section or elevation until they saw an example of a plan enriched by one of these views. The survey showed that even without annotations, the animations could engage students to consider design procedures. One team of three students wrote that they were puzzled, "Why did some designers draw the plan AFTER the perspective?" The examples expose students to new possibilities that generate discussion.

Seeing a designer use the techniques on a familiar problem makes compelling content and emphasizes the efficacy of the techniques. With the animations, students can quickly pick up simple graphic techniques that can increase the quality of their design investigations. Asked what was unexpected, one student said "I did not do preliminary thumbnail sketches in the corner to try out some ideas, which I realized was a great idea when I saw it in the animation. I also didn't draw a grid on the footprint which would have really helped in blocking out the areas proportionally." Students were surprised to see "the number of related sketches done in preparation of design drawing."

In contrast to simple graphic aids that students could easily emulate, more challenging operations were not easily copied. Beginners can identify and understand sophisticated procedures before they can perform them. For example, many beginners can plan logical adjacencies between programmed areas. But in laying out the program spaces, beginning designers have a hard time simultaneously maintaining adjacencies, geometric order as well as area dimensions and proportions. Few students were originally able to get all the program areas close to the requested sizes; looking at examples did not help this skill.

To satisfy multiple requirements, experienced designers often draw ambiguous soft shapes or use thumbnail sketches to test alternatives. Lawson (1980) explains "Good designers tend to be at ease with the lack of resolution of their ideas for most of the design process". Schön (1985) says that an experienced designer evaluates his moves according to "the desirability of their consequences…, conformity or violation of earlier moves and in terms of his appreciation of the new problems or potentials they have created." Watching an animation can't transfer this ability to work with ambiguous shapes and criteria; a designer needs experience to understand what procedures lead to a dead-end.

Furthermore, developing an architectural sketch requires understanding of not only graphic techniques, but also the construction being represented. Experienced designers have implicit knowledge about how to draw entrances, structure, and

furnishings. Beginning designers may not understand the importance of showing these components, not to mention knowing how to draw them, so they have difficulty considering crucial aspects of an environment. Because they struggle with representations, they can't fluidly move between the big picture and the details.

In summary, through the digital sketching lessons, students can learn about the utility of different drawing techniques. They can copy the simpler graphic devices and gain awareness of more complex methods.

VI. Conclusion and next steps

This paper updates progress in making sketch animations useful. We found that it was insufficient to present the raw collection; students need a guide to lead them through. By authoring different kinds of lessons, experimenting with them in the classroom, measuring performance and soliciting feedback, we can stage scenarios where the students get the most benefit from the collection. Rather than supplying comprehensive explanations, the authoring team can draw on the audience to add insights that can enrich the initial information. Together we can develop a robust resource about design thinking.

The study shows how measuring student performance on a task before and after exposure to learning objects can help us understand the inherent challenges. To make a more in-depth study of design drawing, we are currently engaged in using multiple-Item Response Theory, a statistical analysis for education. We can examine the design problem subtasks and dissect how students build up knowledge in different areas to be able to tackle it. The analysis can help us correlate skill sets and domains of understanding. By identifying these domains, we can tailor our lessons to address variable aptitudes in these areas.

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