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Learning Design with Digital Sketching:

Copying Graphic Processes from Animations and Storyboards

CHENG Nancy Yen-wen and MCKELVEY Andrew
Department of Architecture, University of Oregon, USA

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Abstract: This paper examines the effectiveness of animated versus non-animated drawings as teaching tools. Data was collected by comparing how architectural design students given an animation versus those given a static, six-panel storyboard are able to learn processes in a space-planning design problem. All subjects were given an example of an expert design drawing, asked to put the design steps in order, and then to follow those steps in performing a similar design problem. Their responses were recorded with a digital pen-on-paper system that automatically generates vector animations. The animations can then be immediately viewed on a computer for stroke-by-stroke review. Finally, each student's animation was analysed in terms of design process steps and compared with the expert example.

While those given animations performed only marginally better on the survey of steps, they were better able to imitate the order of expert steps. Furthermore, reviewing the examples by computer revealed common errors that students could modify for more successful design strategies. The following discussion examines methods for researching design process with the digital pen, along with shortcomings, advantages and directions for further study.

1 INTRODUCTION, TECHNOLOGY & PRECEDENTS

Teaching design is challenging because experts present processes in large chunks and naturally gloss over subtasks that they find intuitive. Beginners would benefit from seeing projects articulated into explicit subtasks. By recording drawings with a digital pen-on-paper system, we can instantly generate animated sketches that reveal each step in the design process. This paper will discuss the effectiveness of these animated sketches for teaching design.

While stylus-based tablets are a common form of graphic input, mobile digital pens present another level of portability and accessibility. In testing their implications for design teaching, we were inspired by studies that show animations are more effective than static images for teaching physics, that movement helps recall and that picture recall is superior to word recall (Weiss 2000, Sampson 1970). We wanted to see if these results held true for our digital pen animations.

Technology: the project uses the commercially available Logitech digital pen-on-paper to record how expert and student designers draw. The pen's camera captures the location of each mark in relationship to Anita Technology's proprietary printed grid pattern, and then the pen's memory stores the sequence of vectors. After downloading the information from the pen through a USB port, one may view the drawings as an interactive animation on a Windows computer. In the Logitech IoReader 1.01 software, the image appears stroke by stroke in bright blue on ghosted light-grey lines of the completed drawing. While this project specifically uses a Logitech mobile pen, its findings can be applied to animations generated by other stylus-based tools.

Precedents: In teaching design, interactive drawing reveals implicit expert knowledge (Schön 1983). To understand how designers use sketching, we looked at work examining how marks relate to design thinking, how marks are used for specific design operations and how to parse drawing marks and connect them to cognitive processes (Goldschmidt 2003, Do 2000, Ullman 1990, Von Sommers 1984).

Papers from both design and developmental psychology show specific methods for analysing the sequence of operations in a group of drawings and for evaluating sequence recall tasks (Dallett 1968). In drawing, we are strongly influenced by our frame of reference – our background and recent memory shape the world we portray. For example, children shown a complex object pulled apart only draw the newly observed details if they have not already formulated a way to draw it whole. In contrast, successful designers use sketching to transform ideas, reframe the problem, and allow creative solutions to break the original problem definition (Cross 1996). Digital pen animations let us easily collect & examine these sequential operations in detail, assisting accurate recall.

Our students have found these animations helpful for revealing expert approaches to sketching and for analysing their own efforts. Teaching with the pen is documented on the Web (http://www.uoregon.edu/~arch/digsketch/) and earlier papers (Cheng 2004a and 2004b). In collecting design drawings for teaching, we had to narrow the task scope to increase comparability between solutions. We devised a design problem composed of 3 short tasks: interior space planning, lobby redesign and façade design. In winter and spring 2004, we collected 31 examples of the space-planning design task from diverse authors and ran pilot studies of how they were perceived. (Cheng 2004b).

1.1 Hypothesis

From these examples, we sought to determine whether interactively viewing the animated process would be more effective than viewing static examples. We guessed that people who interactively viewed an animated design solution would learn the steps in a design process better than people who look only at a static completed image.

2 RESEARCH METHOD

Our most recent experiment tested how well students understood animated versus still drawings. First we showed subjects a completed solution (as a letter-sized laser print) to office space-planning in an existing shell. After viewing the completed drawing, subjects chronologically ordered a randomised list of six possible design operations (a pre-test). This showed their initial design approach. Next they looked at an expert's step-by-step solution to the space-planning problem, either as an interactive animation or a tabloid-size 6-panel storyboard, and attempted to mimic the expert's process on a similar space-planning problem. We asked them to fit a rock-climbing gym into an existing shell using the Logitech pen to record their work. Finally, we asked the students to answer the initial step sequencing again (a post-test) to measure if there was any change in their design approach.

For this trial, our subjects were twenty students with an average 2.5 years of architectural training who had been drawing about 10.5 years. For convenience we will use the names "Animation group" and the "Paper group." We tested them in groups of one to four viewing the same medium, with the same introduction to the pen technology and the project. All subjects were given a text description of an existing rock-climbing gym with a specified list of spaces that had to fit in. We gave subjects 10 minutes to peruse the example and an additional 20 minutes to do the space-planning problem. This procedure yielded subject surveys and digital examples to analyse.

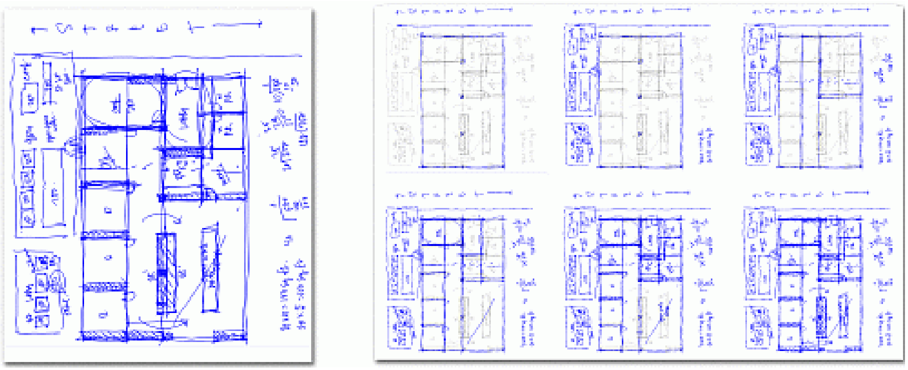

Figure 1 Still image (left) and storyboard (right) of office layout example: 1 site - 2 program - 3 guidelines (right top) 4 planning - 5 articulation - 6 presentation (right bottom)

3 DATA

To analyse the drawings, we looked at the subjects' sequence of design steps and developed a colour bar rating system. From the compiled data we were able to compare student's drawings from both the Paper and Animation groups.

3.1 Step-Sequencing Survey

The task of chronologically ordering design steps showed a slightly better performance from the Animation group than the Paper group. Table 1 summarizes how subjects chronologically ordered the design operations in both the pre-test and post-test. We measured how closely the subjects matched the original example by first subtracting the example's score from the average of each group, then summing the absolute value of these differences. A lower number shows a closer match to the original.

Table 1 Step-Sequencing by subjects viewing an animation or paper storyboard

		All		Animation		Paper		
PRE-TEST: Order of design operations after seeing still image	**Given Example**	**Average**	**Variance from given**	**Ave rate**	**Variance from given**	**Ave rate**	**Variance from given**	**Variance: Paper vs. Animation**
Draw program clusters	2	2.4	0.4	2.2	0.2	2.8	0.8	greater
Define individual rooms	4	3.8	-0.2	4.1	0.1	3.5	-0.5	greater
Strengthen graphics	6	5.7	-0.3	5.7	-0.3	5.6	-0.4	greater
Label rooms	5	5.2	0.2	5.0	0.0	5.4	0.4	greater
Document existing site	1	1.4	0.4	1.5	0.5	1.3	0.3	less
Define major organizing lines	3	2.5	-0.5	2.5	-0.5	2.5	-0.5	same
Sum of absolute values of variances			**1.9**		**1.5**		**2.8**	greater
POST-TEST Order of design operations after seeing animation or storyboard								
Draw program clusters	2			2.3	0.3	2.4	0.4	greater
Define individual rooms	4			3.8	-0.2	3.9	-0.1	less
Strengthen graphics	6			5.9	-0.1	5.9	-0.1	same
Label rooms	5			5.0	0.0	5.0	0.0	same
Document existing site	1			1.2	0.2	1.5	0.5	greater
Define major organizing lines	3			2.8	-0.3	2.4	-0.6	greater
Sum of absolute values of variances					**0.9**		**1.8**	greater

The pre-test shows that most students were able to guess the actual steps just from looking at the still image. However, the post-test does show that the average answer given by the Animation group was more accurate than the Paper group (post test variance from the actual steps of 0.9 vs. 1.8).

3.2 Design Sequence Colour Bars

To compare subjects' design processes we parsed each drawing into a sequence of colour-coded design operations. We used content categories because they are the most useful for conveying the actual work of design. Suwa and Tversky (1997) support the idea that content information makes a richer protocol analysis. By strictly defining the design steps, we created a reproducible coding scheme that produced consistent labelling by three members of the research team.

SITE INFORMATION lines indicate the given building and the area outside of the building, including columns, site boundaries, dimensions of site and north arrows.

PROGRAM lines show relative sizes of program areas and program adjacency relationships, i.e., abstract box or circle diagrams. They do not place the rooms inside the building envelope.

PARTI lines create simple diagrams defining the overall abstract building order.

GRIDLINES help draw other lines and do not demark physical walls or site boundaries.

PLANNING lines organize the building into physical spaces such as initial wall boundary lines and stairs.

ARTICULATION lines define physical elements beyond walls and stairs, i.e., doors, windows and furnishings.

PRESENTATION lines are non-physical annotations such as text and symbols. Room labels alternated with planning lines are not called out as a separate step.

We recorded the chronological steps in Photoshop as labelled layers to create a verifiable visual record. To reveal the sequential pattern of operations, the steps were then recorded in Excel using conditional formatting to give each operation a distinct colour bar: SITE INFORMATION (black), PROGRAM (green), GRIDLINES (purple), PARTI (grey), PLANNING (light violet), ARTICULATION (light peach), PRESENTATION (light blue).

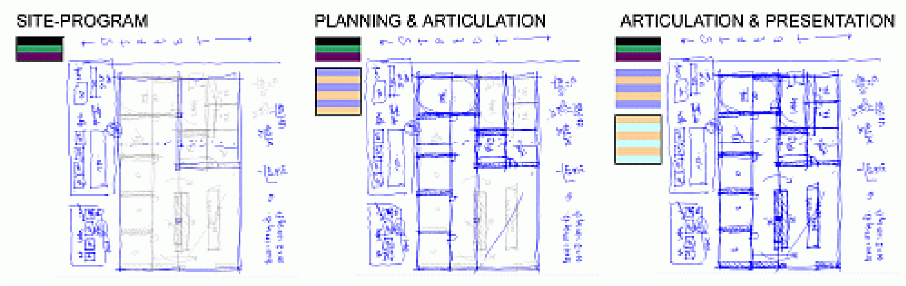

Figure 2 Macro-steps in original example

3.2.1 Similarity Rating with Macro-step Presence and Order

After coding each drawing into a sequence of steps and generating the corresponding colour bars, we identified macro-steps, or larger organizational patterns of the basic steps.

1. SITE-PROGRAM lines alternately describe the site and program. They may contain traces of planning and gridlines.

2. PLANNING-ARTICULATION lines alternately describe building planning element articulation. They may contain traces of planning and presentation.

3. ARTICULATION-PRESENTATION lines alternately describe element articulation and presentation annotation. They may contain traces of planning.

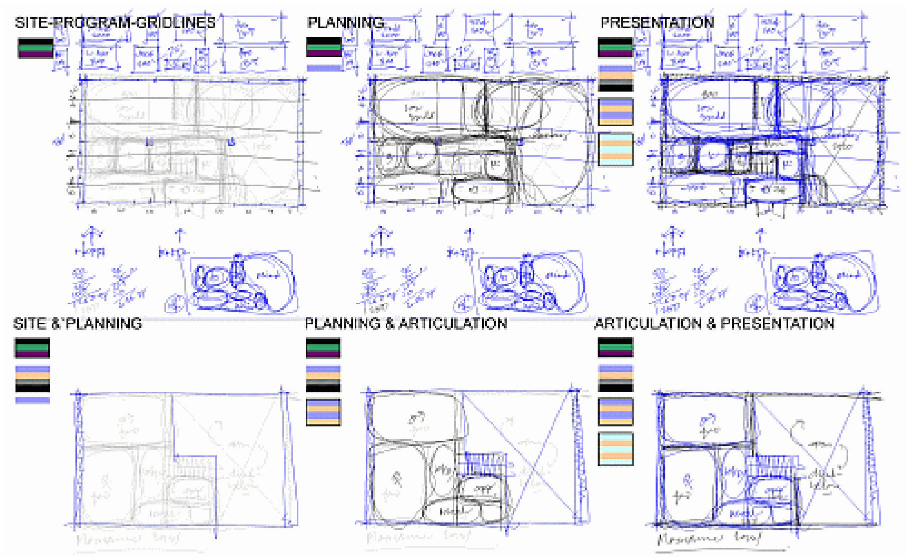

Figure 3 Macro-steps in student copy

We developed a six-point system to rate drawings according to how similar they were to the parent drawing. Each drawing could earn 3 points for presence of the macro steps and 3 points for order. Each subject drawing was given a point for the *presence* of each macro-step pattern, no matter where or how many times it occurs in the drawing. Also, each drawing was given points for *order* if a step occurred in the right sequence in the drawing process. For example, the expert drawing shows all three macro-steps in order so it gets 3 points for the presence of each step and 3 points for having all the steps in the correct order, yielding a perfect score of 6.

Below, Figure 4 summarizes how the macro-steps recur in the Paper group and the Animation group.

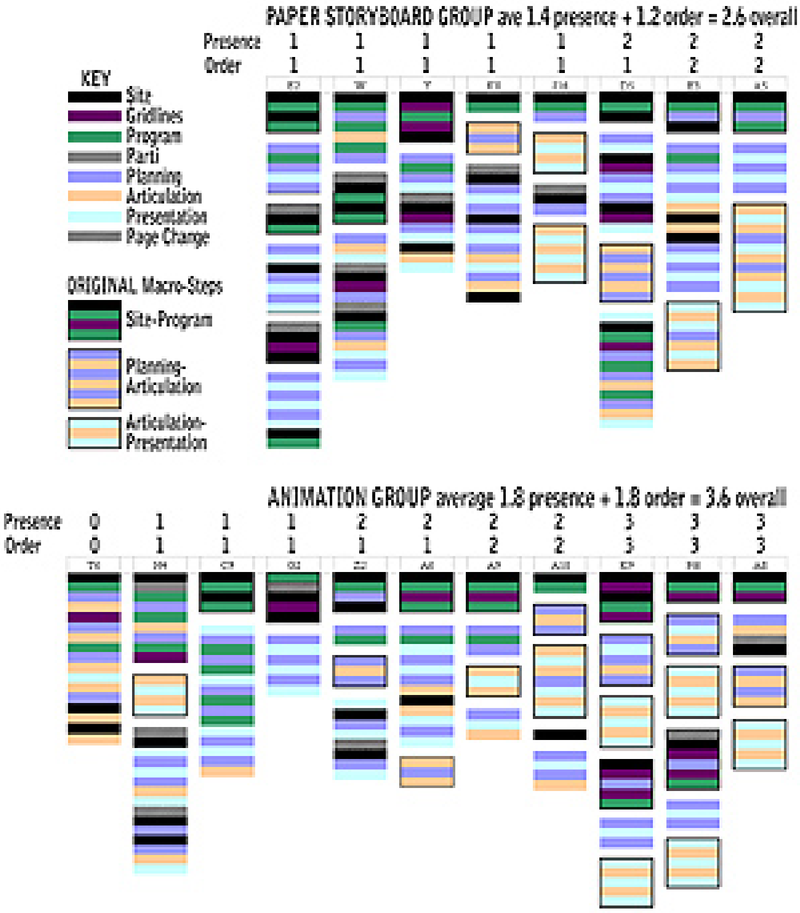

Figure 4 Macro-step scoring – given example patterns on left 4

4 ANALYSIS

From our step sequencing survey, it remains unclear whether an animated or storyboard example increased students' ability to identify and recall a sequence of drawing steps. From our colour bar similarity analysis, we can see that students can better incorporate a series of steps from an animation than from a storyboard into their own drawing process.

4.1 Step-Sequencing Survey Results

While the post-test shows better performance by the Animation group than the Paper group, the difference is not conclusive. The pre-test shows the Animation group had a pre-disposition to seeing the right answers, so it is unclear whether the representation type (animation vs. paper storyboard) made a difference. In considering pre-test versus post-test answers, the Animation group improved 0.6 (from 1.5 to .9), while the Paper group improved more: 1.0 (from 2.8 to 1.8).

4.2 Design Sequence Colour Bar Analysis

Our colour bar analysis shows a distinction between Animation and Paper groups; the Animation group imitated the step sequence of the expert drawing more accurately than the Paper group. Scoring each drawing according to presence and order of the Macro-steps, we found the average score for the Animation group was 1.8 out of a possible 3 points for presence of macro steps, 1.8 out of a possible three points for order of macro-steps, and 3.6 points total. The average score for the Paper group was 1.4 for presence, 1.2 for order, and 2.6 points total.

These data indicate that the difference between the total scores for animated and storyboard drawings is 1.0 point. Given that scores ranged from 0 to 6.0 for a six point maximum range, the 1.0 difference in average score indicates a noticeable separation between the results of the animated and storyboard drawings. The difference in scores indicates that students who viewed animated versions of the expert example were more likely to accurately reproduce the steps of that process.

4.3 Quality Criteria

While quality characteristics generally showed parity between the two groups. specific characteristics reveal that the Animation group stuck to the example more closely.

MULTIPLE SOLUTIONS: The original expert example did not show alternative thumbnail layouts because the office layout problem's simplicity allowed drawing alternate arrangements on top of the existing plan footprint. 39% of the Animation group versus 70% of the Paper group varied from the expert example by creating alternative layout solutions. In this respect, those in the Animation group followed the example more closely. The subjects seeing the paper storyboard took more freedom to do things independently and may have been less engaged by the example.

Need for mezzanine: Both the original office planning problem and the rock-gym planning problem required fitting program spaces into a given existing building. But whereas the given office design example fit all the spaces onto one floor, program spaces for the rock-gym program would not fit on the footprint and required an additional building level or mezzanine. 84% of Animation group versus 61% of the Paper group correctly created mezzanines for the extra program area. We surmise that those looking at the paper example had to spend more time interpreting the information in the example and had less time to reason about their own design solution. Recording how long each subject examined the expert example could reveal the amount of engagement.

Program area accuracy: While subjects generally included all of the program areas and got the program adjacencies correct, they commonly distorted program area sizes to follow the expert example's strong orthogonal zoning. Beginners often drew spaces too small, trying to squeeze them into a rigid order, rather than modifying the diagram or adjusting dimensions. More of the Animation group (78%) was able to roughly match the required program areas than the Paper group (54%). We again surmise that the clarity of the animation allowed the subjects to be more task-focused.

In short, while the Animation group shows better design performance than the Paper group in specific categories, the difference is not conclusive. More importantly, we see no correlation between quality scores and design sequence colour bar pattern matching. So while an animation can help students follow a pattern of design steps, it does not guarantee the quality of results. An animation provides an engaging way to look at a drawing, but it requires the viewer to make judgments about how to separate a continuous process into cognitive chunks. By contrast, a storyboard provides an interpreted guide, encapsulating key moments of the process in a way that can help beginners. Annotating animations with highlighting marks, text or narration could provide both interactivity and interpretation.

5 CONCLUSIONS

So far, we have used the digital pen to 1) begin a substantial archive of design and drawing processes, 2) develop a methodology to investigate the perception of animated versus still drawings and 3) observe subtle aspects of design and drawing that may lead to better results. Our project showed that students who view an interactive animation of a given drawing example are slightly better able to imitate the sequence of operations than students who view a static storyboard version. By colour coding design operations, we could track patterns of design operations. For a more complete story of each design process, we could refer to the animated drawing record.

While our research is not complete, we have already shown that the digital pen has great potential in researching and teaching design processes. Animated drawings can be used to teach any graphic processes involving a prescribed series of steps. They allow teachers to show how initial steps lead to final results in visual thinking.

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