Sketching in Design Journals: an Analysis of Visual Representations in the Product Design Process

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Abstract

This paper explores the sketching behavior of designers and the role of sketching in the design process. Observations from a descriptive study of sketches provided in design journals, characterized by a protocol measuring sketching activities, are presented. A distinction is made between journals that are entirely tangible and those that contain some digitally-produced content ("hybrid journals"). The trend between 2004 and 2006 is an increase in both the average number of sketches as well as in the percentage of 3D sketches for hybrid journals. In 2004, tangible journals exhibited a higher average number of sketches over hybrid journals in the user needs and conceptual design stages, but this trend reversed in 2006 where hybrid journals favored more sketches at all design stages. Text was the predominant form of annotation used (ranging from 62-98%), as opposed to dimensions or calculations for both journal types. The industrial design students had significantly more sketches overall and a higher percentage of 3D sketches. They also tended to annotate more in hybrid journals over tangible journals.

INTRODUCTION

Sketching is a critical part of the design process, providing an outlet for developing design concepts, conveying ideas, and recording and sharing relevant design information. However, sketching is a broad categorization, and there are many different ways that designers visually represent their ideas through sketches. Designers employ varying levels of annotation, detail and representation to explore new ideas or develop previous ideas in more detail throughout the design process. Sketches may be done quickly and informally by hand or rendered digitally with a computer-aided drawing tool. Ultimately, designers make sketches to conceptualize a product or concept and represent their ideas.

It is important to understand how sketches contribute to a designer's thought process and externalization of their ideas toward a final product. Creating sketches is a very useful exercise, as the sketches may serve as reminders of previous ideas, assist in current visualizations, highlight future iterations, and more. This paper seeks to understand the sketching behavior of designers in the design process.

The test bed for this research includes design journals collected from two semesters of a graduate-level, multidisciplinary course titled "Managing the New Product Development Process: Design Theory and Methods" taught at UC Berkeley. The protocol used to characterize the design journal sketches builds on that of Song and Agogino (2004). We focus particularly on patterns in visual representations across these metrics:

- Annotation within the sketches
- 2D or 3D representations

RELATED WORK

The importance of drawing to develop and design a finished product is widely recognized (Ullman 1990). Much research has been done to examine how designers record their ideas and thoughts throughout the design process. Goel observes that designers often make rough sketches in the beginning stages, but become more detailed with their drawings in later design stages (1995). McAlpine et al. take a close look at engineers in particular and how they ideate and create in their logbooks (2006). Yang uses design journals as a data source when analyzing sketching behavior in design teams and found correlations with team performance (2007). Oehlberg et al. explore sketching behavior and how it varies with different media types (2009).

Researchers have also worked in detail to characterize and categorize different types of sketches. Ullman examined annotations in sketches, dividing all "support" marks-on-paper into three categories: Text, Calculations, and Dimensions (1990). McGown's "Level of Complexity" measure (1998) and Shah's Idea Categorization (2003) used different approaches to quantify and measures the level of visual or conceptual detail captured in a sketch.

DESCRIPTIVE STUDY

The data used in this research comes from a new product development course taught at UC Berkeley with participating industrial design students from the California College of Arts. This course engages graduate-level students from Engineering, Business, Information, and Science disciplines and senior-level undergraduate Industrial Design students in a rigorous design project to create a marketable product concept within a four-month semester. The students follow a design process that progresses through three design stages: preliminary investigation and user needs studies (Stage 1), concept generation and development (Stage 2), and prototyping and testing (Stage 3). They work in teams of four to six students each, as assigned by faculty. Each team has at least one representative from each disciplinary field and receives coaching from industry consultants and faculty.

The final project can be a physical product, a software interface, or a service. The final deliverables are a working prototype, a presentation, and a poster or demo for a tradeshow booth. Students are expected to keep a design journal throughout the process to record thoughts, ideas, and observations about their project.

This research performs a retroactive analysis of the sketches from two semesters of this design course, Fall 2004 and Fall 2006, totaling 3,470 sketches from 120 journals, representing 31 design teams. Design journals from industrial designers are only available from 2004 and are thus analyzed separately. Sketches are considered to be any visual representation of an idea, regardless of whether it was drawn by hand, photographed or digitally produced. The protocol used to characterize the design sketches is an extension of that used by Song and Agogino (2004). Each of these metrics measures a unique characteristic of the sketches that collectively help illustrate sketching trends during the design process. They are defined as:

- Representation: Two-dimensional (2D), Two-dimensional with multiple viewpoints (2DM, or 2D Multiview), Three-Dimensional (3D), Three-dimensional with multiple viewpoints (3DM, or 3D Multiview).
- Annotation: "support" marks-on-paper, such as text, calculations, and dimensions. Sketches may have no annotations, one type of annotation, or have multiple types of annotations.

Metrics were also added to capture journal and content media. The journal medium can be tangible (paper-based) or digital (computer-based); likewise the content can be tangible (freehand sketched), digital (computer drawn), or mixed (a combination of both tangible and digital content). For this study, "tangible" journals refer to journals that have only tangible content in a tangible journal; "digital" journals contain only digi-

tal content in a digital journal; "hybrid" journals are tangible or digital journals that contain both tangible and digital content. As there were minimal digital journals, and the few digital journals contained no sketches, this study reports only on tangible and hybrid journals.

The sketch and journal metrics are compared across the three design stages and over the quantity of sketches to capture individual sketching behavior. Figures 1 and 2 provide examples of sketches from tangible and hybrid journals that demonstrate the aforementioned sketch characteristics.

Figure 1. Example of a page from a hybrid journal, featuring 3D photographs with text annotation.

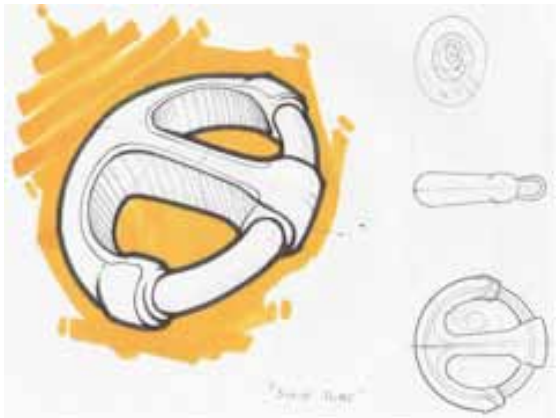

Figure 2. Example of a 3D multiview sketch from a tangible journal, with text annotation.

RESULTS

Table 1 summarizes the average number of sketches per journal produced during a given design phase in 2004 and 2006 for the UC Berkeley students. The results from the design journals of the Industrial Design students from the California College of Arts in 2004 are presented separately in order to isolate trends influenced by the presence of Industrial Design students (Table 2).

	2004		2006	
	Tangible	Hybrid	Tangible	Hybrid
Journal Count				
	29	21	34	24
Average Sketches per Journal				
Stage 1	4.46	2.70	2.24	7.38
Stage 2	16.50	11.90	9.62	15.8
Stage 3	4.93	8.6	4.53	12.45
Overall	25.90	23.28	16.38	35.62

Table 1: Testbed summary, and average sketches per journal at a given design stage. These numbers do not include data from Industrial Designer journals in 2004. Statistically significant results ($p<0.05$) are highlighted in bold.

	2004	
	Tangible	Hybrid
Journal Count		
	6	5
Average Sketches per Journal		
Stage 1	16.83	7.60
Stage 2	48.83	29.60
Stage 3	24.67	13.40
Total	90.33	50.60

Table 2: Testbed summary, and average sketches per journal at a given design stage, for Industrial Designer journals in 2004. Statistically significant results ($p<0.05$) are highlighted in bold.

In both 2004 and 2006, designers generated the highest number of sketches during the second design stage (concept generation and development), followed by the third design stage (prototyping), in both hybrid and tangible journals. These results are consistent with those of Song

and Agogino (2004), adding that these results are independent of journal medium. ¬

As seen in Table 1 for the Berkeley graduate students, the average number of sketches per journal is higher in stages 1 and 2 for the tangible journals and higher in hybrid journals for stage 3. In 2006 hybrid journals dominated in the average number of sketches over tangible journals in all design stages. Among Industrial Design students, the average number of total sketches per design stage was significantly ($p<0.05$) higher in tangible design journals than in hybrid design journals in all design stages (Table 2).

To consistently compare sketching behavior within a design stage, but across years and mediums with significantly varying average sketch volumes, we shifted our unit of analysis from the total number of sketches in a design stage to the proportion of the overall sketches in a design stage that fit a given sketch characterization. We also filtered out any results that did not contribute sketches in a given design stage. This focuses our analysis more on the proportional content of the design journals as opposed to the relative volume of sketches.

Table 3 presents the results from the analysis for the annotation and representation metrics in 2004 and 2006 for the UC Berkeley students. Table 4 presents the results for 2004 Industrial Design students only.

Text was the predominant form of annotation used (ranging from 62-98%), as opposed to dimensions or calculations in both journal types and across all design stages. It is interesting to note that hybrid journals often contained more sketches with no annotations than tangible journals. This effect was most pronounced and statistically significant in 2006 for design stage 3 where 34.07% of the hybrid sketches had no annotations as compared to 11.93% for the tangible journals. One explanation might be that modern solid modeling and CAD programs allow for embedded annotations in the software for use in analysis, but students may not feel the need to print out these annotations for archiving in their journal.

	2004		2006	
	Tangible	Hybrid	Tangible	Hybrid
Design Stage 1				
Annotation				
Text	91.78%	98.00%	93.10%	81.19%
Dimension	-	-	-	-
Calculation	-	-	-	-
None	8.22%	2.00%	6.41%	18.81%
Multi	-	-	-	-
Representation				
2D	52.98%	84.08%	71.57%	51.57%
2DM	2.88%	3.25%	-	-
3D	44.15%	11.42%	26.09%	48.11%
3DM	-	1.25%	-	0.32%
Design Stage 2				
Annotation				
Text	85.44%	79.65%	86.89%	81.07%
Dimension	5.40%	3.68%	-	-
Calculation	-	-	-	-
None	9.03%	16.45%	10.28%	16.55%
Multi	15.34%	8.75%	2.83%	-
Representation				
2D	63.66%	74.74%	51.68%	57.84%
2DM	2.82%	2.77%	0.70%	0.39%
3D	32.67%	20.81%	47.17%	41.77%
3DM	0.85%	1.32%	0.22%	-
Design Stage 3				
Annotation				
Text	73.26%	74.04%	84.20%	62.41%
Dimension	5.97%	8.36%	1.21%	0.59%
Calculation	-	-	-	-
None	17.79%	18.47%	11.93%	34.07%
Multi	4.06%	4.75%	2.67%	2.92%
Representation				
2D	77.61%	63.03%	42.45%	42.59%
2DM	3.32%	0.93%	-	0.82%
3D	19.07%	34.48%	56.96%	52.50%
3DM	-	1.97%	0.59%	2.27%

Table 3: Summary of results from the analysis of the proportionality of metrics at a given design stage, within the set of journals of a given medium that contributed sketches to that design stage. Statistically significant results ($p<0.05$) are highlighted in bold. These results do not include the 2004 Industrial Designers.

	2004	
	Tangible	Hybrid
Design Stage 1		
Annotation		
Text	62.28%	72.28%
Dimension	-	-
Calculation	-	-
None	37.72%	27.72%
Multi	-	-
Representation		
2D	54.90%	61.13%
2DM	1.55%	-
3D	43.54%	37.90%
3DM	-	0.96%
Design Stage 2		
Annotation		
Text	22.36%	65.97%
Dimension	0.21%	-
Calculation	-	-
None	67.03%	33.36%
Multi	-	-
Representation		
2D	37.03%	15.49%
2DM	7.86%	1.66%
3D	54.94%	81.0%
3DM	0.15%	11.84%
Design Stage 3		
Annotation		
Text	18.77%	55.03%
Dimension	0.98%	2.08%
Calculation	-	-
None	61.11%	40.06%
Multi	-	4.35%
Representation		
2D	47.00%	63.03%
2DM	4.41%	2.27%
3D	46.52%	36.42%
3DM	2.04%	0.69%

Table 4: Summary of results from the analysis of the proportionality of metrics at a given design stage, within the set of journals of a given medium that contributed sketches to that design stage, isolating the effect of the Industrial Designers in 2004. Statistically significant results ($p<0.05$) are highlighted in bold.

The trend between 2004 and 2006 is an increase in the percentage of 3D sketches for tangible journals in design stages 2 and 3 and in all design stages for hybrid journals.

In 2004, the tangible design journal users had a significantly ($p<0.05$) higher average percentage of 3D sketches than their hybrid journal counterparts in design stages 1 and 2, while the hybrid journal dominated the 3D sketches in stage 3. This trend reversed in 2006 where the hybrid journals had the higher number of 3D sketches in design stage 1 and a relatively equal balance with tangible journals in design stages 2 and 3.

The 2004 Industrial Design students (Table 4) had a much higher percentage of 3D drawings in all design stages than the students from other disciplines (Table 3). Among the Industrial Design students the hybrid journals had a higher percentage of both 3D and annotated sketches than the tangible journals.

DISCUSSION

From the descriptive analyses of designers' journals and their sketching behavior, the following overall observations are presented.

- Design journal use varies across design phases.

Although designers are using their journals to support all steps of the design process, these journals are not being used in the same manner at each stage. Song and Agogino (2004) demonstrate that factors including generation vary from design stage to design stage. In this study, the increase of sketches in the second design stage was confirmed. Other factors also produced variable results over time, such as representation and annotation.

- Industrial designers' sketching behavior is dramatically different from that of other disciplines.

The average number of sketches across all design stages for the industrial designers was 90.33 and 50.60, respectively for tangible and hybrid journals. The corresponding numbers for the

journals by students in the other disciplines (Engineering, Business, Information, Science) were 25.90 and 23.28. The industrial designers also tended to draw more of their sketches in 3D. This trend was most pronounced in the conceptual design stage 2 with hybrid journal users (81.0% versus 20.8%). This stark contrast raises the question of whether engineering students would benefit from industrial design pedagogies and approaches to sketching.

- Increased technological fluency is changing the way designers sketch and visualize ideas.

Comparing the 2004 and 2006 results illustrates the increasing pervasiveness of digital technology within our tangible information worlds; not only have designers been shifting to hybrid journals instead of exclusively tangible journals over the past few years (Oehlberg et. al, 2009), but the 2006 hybrid journal users are also representing a higher percentage of their ideas in three-dimensions instead of two. We hypothesize that this higher-degree of representation is due to the increasing use and influence of digital tools such as CAD, digital cameras and photography, and access to information and graphics over the internet.

CONCLUSION

This paper has explored variations in content in the practice of design journals. A comprehensive descriptive study of student journals in multifunctional graduate design teams over two semesters was performed. The results highlight trends and affordances associated with the representation and annotation sketch characteristics among tangible and hybrid journals. This analysis provides a basis for future research in developing design journals to support efficient ideation and realization of concepts in the product design process.

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