DEVELOPING A TAXONOMY FOR FREEHAND SKETCHING IN DESIGN

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ABSTRACT
Taxonomy can be helpful in characterising the roles of the sketch in design. Various attempts have been made to classify design sketches. Ferguson developed widely accepted sketch taxonomy and showed how sketches are used in the design process using the classes of thinking, talking and prescriptive. However, some limitations of the original taxonomy have been found in practice due to professional and technological changes of the last 20 years. Therefore, an empirical study was conducted with the aim of investigating the implementation of the established design sketch taxonomy, revealing its specific limitations, and thereafter seeking to enhance and revise this taxonomy so that it can meet the needs of today's design students and trainers. The empirical study utilised a qualitative research methodology, incorporating sketch observation and follow-up interviews of participants during a 2-day product design workshop. The outcome of the research was an enhanced design sketch taxonomy aimed at providing guidance for both design education and practice.

Keywords: Sketch, sketch taxonomy, roles of design sketch, design education

1 INTRODUCTION
Freehand sketching has traditionally been considered an essential part of the design process. Designers are generally taught to think with their sketches in order to externalise concepts, communicate ideas and solve complex problems. Understanding the roles of sketching in design can be expected to have important implications for both design education and design support tool development. Taxonomy can be helpful in characterising the roles of the sketch in design. As Simon [2] pointed out: "an early step toward understanding any set of phenomena is to learn what kinds of things there are in the set—to develop a taxonomy". To achieve a fully rounded understanding of the design sketch, various sketch taxonomies have been developed. This paper selected widely accepted sketch taxonomy and conducted an empirical study to investigate its implementation in the contemporary design context. The original taxonomy was developed by Ferguson [2] and has been instrumental in helping to characterise sketches. However, the impact of technological changes in the last twenty years has had a marked influence on the role of sketching in commercial practice, which has also led to profound changes in the teaching of sketching in design education [3]. The aim of the research presented in this paper was two-fold. Firstly, to identify the major drawbacks which limit this taxonomy effective implementation in the design process. Secondly, to enhance and revise this taxonomy so that it can meet the needs of today's design students and practitioners. A mixed methodology has been adopted, which involves a literature review; identification of limitations via practitioner interviews/observations; and improvement of a taxonomy for the design sketch. The outcome of the research was an enhanced design sketch taxonomy aimed at providing guidance for both design education and practice.

2 OVERVIEW OF DESIGN SKETCH TAXONOMY
Table 1 gives an overview of different sketch taxonomies found in the literature relating to design sketches. Design sketches can be considered and classified from several perspectives. Ferguson [2] identified three different types of sketches according to their functions in the design process, i.e. thinking, prescriptive and talking sketches. Ullman et al. [4] argued that a sketch may be used as a means of storing ideas so that they can be revisited in the future. Following this line of research, Lugt

[5] called this type a 'storing sketch' and combined it with Ferguson's taxonomy. Fraser and Henmi [6] analysed architectural drawings and suggested taxonomy based on the characteristics of drawings. Based on this research, Lawson [7] tried to develop a more elaborate taxonomy addressing the way in which knowledge is manipulated in designers' minds. Both these taxonomies pay little attention to the early design stage, but they identified two types of sketch: 'visionary drawings' and 'fabulous sketches', which are believed to be associated with idea development processes. The taxonomy presented by Goel [8] describes the ideation process and used a cognitive approach to classify sketches and identifies two types of operation occurring in a design sketch, 'lateral transformation' and 'vertical transformation'. McGown et al. [9] presented taxonomy according to the level of complexity of sketches. Features such as the use of annotations, shading and colour can be used to differentiate the complexity of the sketch. Both Olofsson et al. [10] and Pei et al. [11] classified sketches according to the need or intention of the designer during the sketching process. The difference is the former taxonomy focuses on the initial stage of the design process while the latter puts more emphasis on the late stage of the design process and involves CAD/ physical models of the designed product. The taxonomies proposed by Pipes [12], Yang [13] and Huet et al. [14] all classify and analyse sketches according to their forms, which focus more on how ideas are represented in the sketches rather than how the sketches are used. This study adopts three taxonomies based on the existing literature

Table 1. A list of different Sketch taxonomies found in the literature

Author/Year	Types of Sketches
Ferguson/1994;Lugt/2005	Thinking sketch; Talking sketch; Prescriptive sketch; Storing sketch
Fraser & Henmi/ 1994	Diagrams; Referential, Design, Presentation and Visionary drawings
Goel/ 1995	Lateral transformations; Vertical transformations
McGown et al. /1998	Level 1; Level 2; Level 3; Level 4; Level 5
Olofsson & Sjölén/ 2005	Ideation sketch; Explorative sketch; Explanatory sketch; Persuasive sketch
Menezes /2005	Orthogonal drawings; Axonometric drawings; Perspective drawings
Pipes/ 2007	Thematic sketch; Package-constrained sketch
Yang/ 2009	Non-dimensioned sketch; Dimensioned sketch
Huet et al./ 2009	Chronologically; Type of view; Subject
Pei et al. / 2011	Personal sketch; Shared sketch; Persuasive sketch; Handover sketch
Lawson/ 2012	Presentation, Instruction, Consultation, Experiential, Fabulous, Proposition, and Calculation drawings; Diagrams;

3   METHODOLOGY

An empirical study was undertaken with the aim of investigating the implementation of established design sketch taxonomy, revealing its limitations, and thereafter, to enhance and revise this taxonomy so that it can meet the needs of today's design students and trainers. The research study presented in this paper was conducted following a toy design workshop at the Zhejiang Normal University. In total 33 third year industrial design students attended the workshop and they were divided into 6 groups. A 2-day study was undertaken during the workshop and 6 sketchers were selected from 6 groups as subjects. These subjects vary in terms of sketching experience, from 3 years to 6 years, but they were qualified design sketchers and all of them are familiar with the taxonomy.
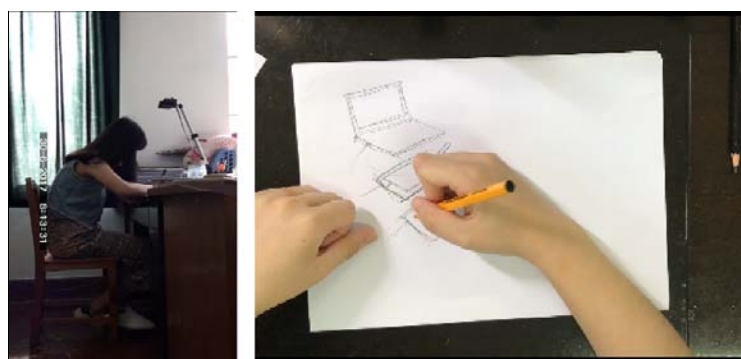

Figure 1. Experimental setting and activity

The empirical study utilised a qualitative research methodology, incorporating sketch observation and follow-up interviews of participants during a product design workshop. Observations were used to obtain detailed information by being close to the field of study. The task set was to design a toy which may help in stimulating children's creativity. The 6 sketchers were asked to work on the task for one hour while sketching on paper. All sessions were recorded on two video cameras. One camera captured the general movements and gestures of the subject while the other focused on the paper on which the subject was drawing. Standard ethical protocols were adopted for the study.

After the sketching process, individual interviews were conducted with the participants. Each interview was audio-taped and transcribed. The interviews comprised open-ended questions that allowed respondents to fully describe their personal experiences relating to design ideation, classification of sketches and strategies for selecting types of sketches, which included questions such as: What types of sketches did you use? Where in the design process did you use them? What were the strengths and weaknesses of the sketch taxonomy? The research material, as recorded in the interviews, was collected as data and analysed with a coding and clustering method. Transcriptions were coded with short words or phrases and then data labelled with the same code grouped into clusters. For example, all data labelled as "non-working" were grouped.

4   RESULTS AND FINDINGS

The data in the form of sketches, video records of the sketching process and the audio records of the follow-up interview were analysed. To aid analysis, some data were presented to the participants in follow-up interviews. The aim of the analysis was two-fold. Firstly, to identify the major drawbacks that limit the effective implementation of this taxonomy in design; secondly, to identify the types of sketches that designers tend to use in today's design context. Transcripts of the session were summarised according to each participant in a spreadsheet. In total, 12 problem categories were identified. By adopting a coding and clustering technique, the results were then condensed into a matrix based on recurrence and importance. These 12 problem categories can be further categorised into the following three distinct headings:

1.   Problem Category A – Lack of hierarchical structure. Ferguson's taxonomy has its limitations, as one type of sketch may serve multiple purposes at different stages in the design process. The revised taxonomy should sub-divide the original sketch category with a hierarchical structure to address this point.
2.   Problem Category B – Out of date. Due to the impact of technological changes in the last 20 years, several types of sketches have been replaced by CAD software, including prescriptive sketches identified by the original taxonomy.
3.   Problem Category C – Lack of integrity. Due to overlooking the non-working sketches, the original taxonomy is incomplete and fails to involve several important types of sketches, such as fabulous, practising and playing sketches.

From this section on, the findings will be presented according to the 3 methods that are used to identify the types of sketches. The findings are tabulated (the first row identifies types of sketches; the second row the frequency of occurrences/mentions). Regardless of the number of times any contributing factor occurred/is mentioned, it was only counted once. Therefore, the maximum possible frequency is 6. Drawing from the video recordings and design sketches, we have identified 7 types of sketches that were used in the design task (table 2). These types of sketches emerged from the many different ways that participants used sketching in the design process. Analysis of the results enabled confirmation of the preferences and choices of design students when they are sketching during a product development process. According to the analysis of the interview transcripts, another 2 types of the sketches were identified which are normally used for facilitating the design communication, namely explanatory and prescriptive sketches. In addition, it also helped us to confirm the existence of 3 types of sketches found in the literature (table 3).

Table 2. Types of sketches identified in the design task

Defining Sketch	Memory Sketch	Idea Sketch	Development Sketch	Explanatory Sketch	Storing Sketch	Warming-up Sketch
5	3	6	4	3	2	2

Table 3. Types of sketches identified from interview

Presentation Sketch	Prescriptive Sketch	Playing Sketch	Practising Sketch	Fabulous Sketch
6	4	3	5	4

5   DEVELOPING THE NEW TAXONOMY

The hierarchical classification in Figure 2 illustrates the arising framework for the revised taxonomy. This study initially broadly classified sketches according to the established roles sketches play in design, namely: thinking, talking and non-working sketches, and these have then been sub-classified into 12 types of sketches, each of which is now described.
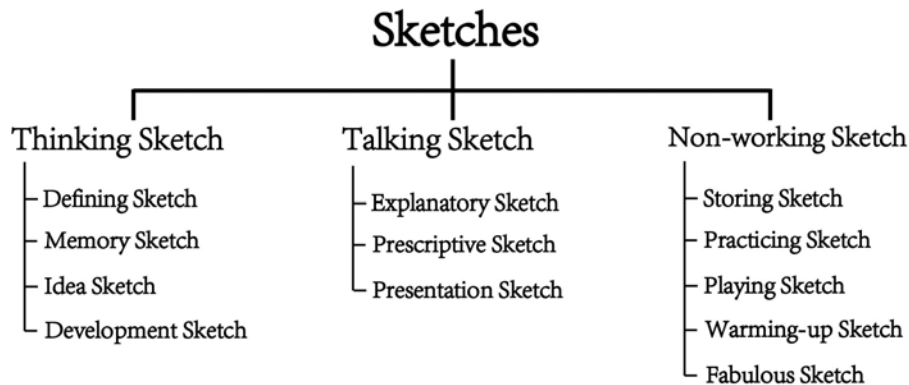
Figure 2. Taxonomy of Visual Design Representations

5.1 Thinking sketches

Thinking sketches are a group of sketches that designers use to support their individual thinking processes. According to [2] engineers use the thinking sketch "to focus and guide nonverbal thinking". The grouping of thinking sketches comprises defining, memory, idea and development sketches. The purpose of a defining sketch is to help the designer to define and clarify the task. This stage is the starting point of the entire design process, which begins with an initial statement of the need and problem analysis. The memory sketches are used by designers to expand their thoughts and recall elements from previous work with the help of mind-maps, notes and text annotations. Idea sketches help designers with the visualisation of their thoughts and design ideas. It emphasises the abstract nature of a sketch, which tends to be used at the early design stage to assist designers converting a single idea into more than one potential design solutions. The aim of a development sketch is two-fold, first it is to evaluate and select those ideas generated in the former stage, and second is to develop the ideas by investigating their appearance, proportion and scale in greater detail than an idea sketch.
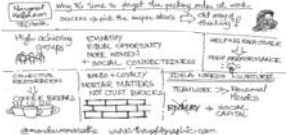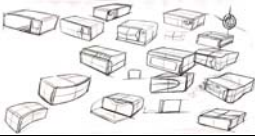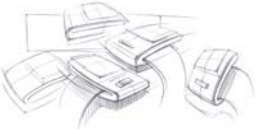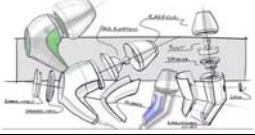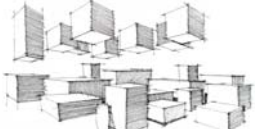
5.2 Talking sketches

Talking sketches are used for facilitating design communication. They encourage discussion and build a common understanding of the design idea among the parties involved. According to the different parties they serve, i.e., designers, engineers and clients, this group of talking sketches can be further divided into 3 categories as explanatory, prescriptive and presentation sketches. Explanatory sketches are used to quickly and effectively convey the design intent or features with other designers in the team. Ferguson [2] describes the prescriptive sketch as the means for an engineer "to direct the drafter in making a finished drawing". However, this type of sketch is produced by CAD tools instead of freehand. It has evolved into a type of informal coded representation or sketches for designers to communicate technical details such as mechanisms, manufacturing and dimensions with engineers. Presentation sketches are rendered and realistic sketches to help designers to communicate formal proposals of design concepts with clients, which often employ the use of colour/tone to enhance detail for realism.
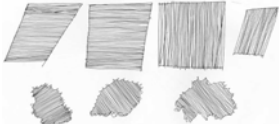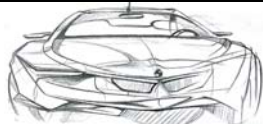
5.3 Non-working sketches

Non-working sketches can be defined as a group of sketches that are produced by designers outside the design process in their spare time. As Lawson pointed out: "Designers tend to draw habitually and

certainly more often than just when designing". Empirical evidence supports that the non-working sketches may also play a helpful role in the design process. The non-working sketches group comprises the storing, practising, playing, warming-up and fabulous sketches. Storing sketches can be viewed as an external memory device, which can record ideas or observations for future reference or as a metaphor. As a learned skill, expertise in sketching requires lots of practice. Therefore, practicing sketches are often extensively used by designers for the purpose of improving their sketching skills. Playing sketches are produced by designers in their spare time simply for fun, enabling designers to 'toy with' and explore their sketches and ideas. Warming-up sketches tend to be produced at the initial stage of the sketching process, which may help the designer to quickly enter the drawing state. The fabulous sketches are used to present design ideas in a way that is intended to express its wonderful or fantastic qualities. Lawson suggested that "they tend to represent something that could not exist in the reality. They thus suspend disbelief and criticism and realism. This characteristic seems important in assisting the development of creative thought in some of its stages." A summary of the various types of sketches discussed in this section is shown in Table 4.

Table 4. Taxonomy of design sketches

Sketch Category	Sub-category	Definition	Visual Example
Thinking Sketch	Defining Sketch	Helps the designers to define and clarify the design task	
	Memory Sketch	Used by designers to expand their thoughts and recall elements from previous work	
	Idea Sketch	Promotes idea generation and exploration of alternatives with simple line drawings	
	Development Sketch	Used to evaluate design ideas and further investigate the appearance, proportion and scale in greater detail	
Talking Sketch	Explanatory Sketch	Encourages discussion, produced to share and explain an idea to other designers	
	Prescriptive Sketch	Informal sketches for facilitating design communication with engineers regarding technical points	
	Presentation Sketch	Rendered and realistic sketches to help designers to communicate the design concept with clients	
Non-working Sketch	Storing Sketch	Drawing records of relevant design information for future reference	
	Practising Sketch	Extensively produced by designers for the purpose of improving their sketching skills	

	Playing Sketch	Simply produced by designers for fun, enabling them to play with sketches and ideas	
	Warming-up Sketch	Produced as a warm-up exercise for designers to quickly enter the drawing state	
	Fabulous Sketch	Used to present design ideas in a way that intend to express wonderful or fantastic qualities	

6 CONCLUSIONS

The implementation of established design sketch taxonomy has been investigated revealing its limitations, and a revised version proposed to enhance understanding of the changing roles of sketching in design and design education. An empirical study has contributed new insights into factors that affect the effective use of the original taxonomy, namely: a lack of hierarchical structure (failure to reveal the complexity and diversity of the roles of sketching in design); being out of date (failure to meet the technological and professional changes); and lack of integrity (overlooking the supporting value of non-working sketches). A revised sketch taxonomy has been proposed, defining the types and corresponding roles of sketches used by industrial designers in the product design process. This taxonomy uses three classes consisting of thinking, talking and non-working sketches, which are defined as the top-level categories and further, expanded in 12 sub-categories. It is expected that this taxonomy will be useful in supporting the development of new design tools and deepening knowledge in the field. It would be beneficial to test and collect real needs from design students and practitioners to further improve the revised sketch taxonomy through case studies.

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