Chapter III
The Power of Design Drawing in Other Design Fields[1]

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ABSTRACT

This chapter is a survey of the literature of design studies, where the various characteristics of a phenomenon called design drawing, are considered. Included in this review is an exploration of the roles and attributes design drawing plays in those design fields outside ID, as an important design language. Its importance to those design fields suggests that design drawing might have much to teach us about visual instructional design languages (VIDLs).
In reviewing these attributes of design drawing and how they are implemented in those other fields of design, we hope to inspire a dialogue on how these important characteristics will aid in creating or nurturing VIDLs.

INTRODUCTION

In this chapter, we will explore the roles and attributes of design drawing, which serves as an important design language in design fields outside of ID. Its importance to those design fields suggests that design drawing might have much to teach us about VIDLs, if we knew more about it.

We will show that, due to the similarities between ID and other fields of design, we might expect that tools, skills, and methods important in those fields—such as design drawing—might also be valuable to ID. The basis of design drawing's importance in those fields lies in the common characteristic of all design fields' need for models and representations, which design drawing per-

forms capably. In fact, we will show that there are a number of characteristics of design drawing which make it attractive to designers in those fields: its close association with design thinking, its language-like characteristics, the fact that it can adroitly represent all stages of design with a number of expressive forms. Design drawing can also be as concrete or vague as it needs to be to support the design at hand—there being a real advantage to a definable level of vagueness. This characteristic also makes it ideal for working with ill-defined problems, which design is usually characterized to be. Design drawing plays a crucial role in a dialectic (called "the dialectic of sketching"), which some authors (Arnheim, 1995) suggest is essential to design. Drawing, which is often accompanied by some kind of narrative, forms the basis of a shared vision of the design: a catalyst for the social agreement necessary for design to move forward.

In reviewing these attributes and their application in those other fields of design, we hope to expose to ID practitioners to the characteristics of this important design language. This might, in turn, begin an important dialogue on some important characteristics to consider when creating or nurturing a VIDL.

IS ID DESIGN?

Murphy (1992) asks, "Is instructional design truly a design activity?" After comparing ID to the general practice of design (as found in architecture, industrial design, engineering, etc.), he concludes, "…it can be argued strongly that instructional designers are truly involved in design activities" (p. 281). And, further, "…instructional designers need to recognize their links with the wider world of design" (p. 282). Rowland (1993) conducted a similar analysis and similarly concluded, "Designing instances of instruction, or more generally, planning and preparing to instruct, can be considered a subset of designing, and the defining characteristics…for all types of design appear to hold true for ID" (p. 87). Speaking of the literature on ID, Rowland adds that the results of his study, "…match studies of design processes in other fields, but contradict views in the literature on ID, especially those representing a purely rational perspective" (p. 90). Murphy is emphatic: "Thus far, it appears that not much has been done on the design skills of instructional designers," and warns, "All you instructional designers out there, look and learn from the design world. You ignore it at your peril" (p. 282).

In that larger design world, as in ID, design takes place in the gap between the mind of the designer and how the problem and solution are represented—design is the bridge between the conceptual world within and the physical world without. Simon (1996) puts it this way: because the gap is, "…centered precisely on this interface between the inner and outer environments; [design] is concerned with attaining goals by adapting the former to the latter" (p. 113). Bridging this gap requires a process of externalizing the designer's conceptual world. This externalization may be expressed verbally, visually, or physically—with words, drawings, or models.

For many fields of design, the fundamental bridge is drawing. Archer observes, "It has sometimes been said that drawing is the language of design. There has certainly been an intimate relationship between drawing and design from time immemorial… All the design professions today rely heavily upon drawings of various types for both the development of ideas and the communication of findings." Arnheim reports, "The function and nature of [drawing] is inseparable from that of the design it serves. The creative process of designing, being an activity of the mind, cannot be directly observed. The [drawings], done for the eyes and being directed by them, make some of the design plans visible," which makes drawing the perfect bridge across "Simon's gap" (See also Goldschmidt, 1991).

Robbins (1994) has pointed out, "Because drawing is used to communicate ideas and to instruct others about a design, it is often seen as a language. Architects, when speaking about drawing, assume…that drawing may be construed to be a language or quasi-linguistic order of communication" (p. 27–28). Design drawing can be considered a language of design.

In ID, visual representations serve two very different purposes. First, visual representations, including drawing, are used during design as part of the design process to represent some aspect of instruction before it has been produced or presented. This may be in the form of storyboards, flowcharts, etc. Because the product of ID is instruction, visual representations may also serve as part of the content being produced. These may take the form of illustrations of the content or diagrams of concepts, etc. (A more complete taxonomy is presented in Chapter XVII).

The latter—visual representation of content—has been studied extensively to determine how it contributes to learning. Unfortunately, the former—visual representations that are used to further the design itself—have not. Schatz (2003) did a small review of the literature of ID where he noted that it is difficult to find literature on design thinking or design methods in ID, much less a specific method like design drawing. It is a paradox that a field that relies so heavily on visualization for the outcome of its designs has not studied its use in its process. In spite of the apparent similarities between ID and other design fields, and the importance of drawing to design in those fields, design drawing as a tool or skill of ID has not been adequately addressed in the ID literature.

DESIGN DRAWING AS AN ESSENTIAL PART OF DESIGN

A large share of the research in design drawing comes from a field of inquiry called *design studies*. The last decades of the 20th century saw a great deal of research in the study of design methodology as a general field, where the various creative design activities of architecture, engineering, industrial design, graphic design, software engineering, and others were discussed, compared, and analyzed, in an effort to improve methods and process models. This new field of inquiry was called variously design methodology, design theory, design science, and design studies. The importance of this field is evident by the number of research-based journals in design theory and methodology, such as *Design Issues*, *Design Journal*, and *Design Studies*, among others. (Kays, 2003). This literature (in which ID is not generally included) contains a wealth of information on design drawing and its relation to the design process.

In this literature of *design studies*, it has been observed that drawing and design have a long history together. Baynes (1992) identified the development of design drawing in the late 18th century as the principle catalyst to the development of design as a separate discipline, which, in turn, helped to fuel the industrial revolution. However, the use of some kind of drawing to pre-plan work predates the industrial revolution by millennia. Shards of pottery and stone with coarse building directions on them have been found from ancient Egypt (Baynes, 1992).

Press and Cooper (2003) pointed out that "…everyone can draw; however, designers are trained to develop this as an advanced form of communication." Lockard (1977) has observed that, "In…the design process, drawing is still the most flexible and efficient means of representation." This is in part because the speed and ease of production of free-hand sketches support design in important ways. According to Kivett (1998) free-hand sketches allow communication to be almost instantaneous, and drawing facilitates making of changes "on the spot." Referring to sketching, Gedenryd (1998) asserts that,

Sketching is made up of very small and simple incremental steps, which yield to local control and

high sensitivity to feedback. This, in turn, makes sketching into a highly fluid and efficient process, which supports the open-ended and conceptual nature of the design work which sketching is typically used for.

Goldschmidt and many of others assert that drawing is a vital part of design (Archer, 1992; Goldschmidt, 1991; Henderson, 1998; Moore, 2000; Ullman, Wood, & Craig, 1990). For example, Ullman, Wood, and Craig say that,

The evidence both from research in cognitive psychology and from the protocol studies of designers points to the importance of drawing in the design process beyond the documentation of final designs. Not only are drawings the preferred form of data representation, for the designer, but they are a necessary part of the design process. Sketching as a form of drawing has been shown to have properties that make its use important in design.

Many have speculated on the reasons for the close association between design process and design drawings. Some have investigated the relationship of design drawing to specific design activities of which drawing seems to be a part; others have looked at specific processes and properties of design drawings that support design. Still others have studied the close association between design thinking and drawing. What follows are summaries of these ideas.

THE IMPORTANCE OF REPRESENTATIONS & MODELS TO DESIGN

Designers rely heavily on representations and models to accomplish their work. According to Goel (1995):

Design, at some very abstract level, is the process of transforming one set of representations (the design brief) into another set of representations (the contract documents). However, not only are the inputs and outputs of the of the design process representations, all intervening transformations are also typically done on representations.

Saddler (2001) observed, "We use sketches, diagrams, specifications, even verbal descriptions throughout the design process to make the concepts in our heads tangible and communicable." These representations are sometime referred to as models. Representations and models are referents (symbols or metaphors) for some other (real-world) thing. Baynes (1992) says,

The term 'model' is used by scientists, mathematicians, technologists, and designers to mean something that stands for something else. In general, models are powerful because they isolate an aspect of reality and allow us to represent, interpret, manipulate, or control it. Models have predictive power because…they can be 'run' to simulate what will happen if proposed changes are carried out. They are indispensable for design activity because they allow designers to develop their designs and understand their likely effects before they are put into practice.

Goel (1995) adds:

This [practice of using models in design] is not an accident…Recall that design typically occurs in situations where it is not possible or desirable to tamper with the world until the full extent and ramifications of the intervention are known in advance. After all, we only get one 'run' on the world. Every action is irrevocable and may have substantive costs associated with it. Thus, it is not surprising to find that designers produce and manipulate representations of the artifact rather than the artifact itself. All the reasoning and decision making (including performance prediction) is done through the construction and manipulation of models of various sorts, including drawings, mock-ups, mathematical modeling, computer simulations, and so on (p. 128).

Henderson (1998) observes, "design cultures are intrinsically tied to the way in which their representations are constructed because such representations—sketches, drawings, prototypes—are the heart of design work."

CHARACTERISTICS OF DESIGN DRAWING

Design Drawing and Thinking

Much of the literature about design drawing proclaims the close tie between it and thinking. So much so, that the rest of the topics about drawing that follow in this chapter could be considered, more or less, to be subsidiary to this idea. As Robbins (1994) puts it, "Unless you draw something, you do not understand it" (p. 127).

Design drawing aids the designer by reducing cognitive load during the design process. Because design sketches are an external representation, they augment memory and support information processing (Tversky, 2002).

It is probably this support of memory that gives design drawings, "…the capacity to transform our understanding of an issue, and, to some extent, free us from the narrowness of words, labels, and classification systems." (Hansen, 1999, p. 203). Laseau (1989), a theorist in design drawing, calls this close affiliation between drawing and thinking *graphic thinking*: "The term *graphic thinking* distinguishes the use of graphics in support of thought from graphics used in presentations. Graphics should play a significant role in design and problem solving, provoking thought and acting as catalysts for ideas rather than limited representations of products or decisions" (p. 9, italics in original).

Another view of drawing is similar to Vygotsky's description of the relationship of language to thought. Substituting drawings for words, Vygotsky says: "Thought is not merely expressed in [drawings], it comes into existence through them." This seems to be Goel's view, that in his research, design sketching, "played an important role in certain types of open-ended, explorative cognitive processes," different from mere problem-solving. It is also consistent with McKim's (1980) understanding of the role of drawing in design, that "…drawing and thinking are frequently so simultaneous that the graphic image appears almost an organic extension of mental processes" (p. 11).

All this is dependent on the designer's ability to express (or illustrate) an idea in a variety of ways. "In both the exploratory and developmental mode, graphic ideators [e.g., designers] use many graphic idioms. When you are sketching from life or communicating a visual idea to others, you can be content with one graphic idiom. But when you are exploring ideas, you must use graphic language more flexibly…"(McKim, 1980, pp. 134–135) Verstijnen et al. (1998) observed the differences between skilled sketchers and unskilled sketchers, and concluded that the skilled sketchers benefited most from the visual representation in a sketch. When Lockard (1977) compared drawing to a language, he noted that, if the designer has a limited "vocabulary" of drawing skills, he will be plagued by "curious speech stoppages and deadly dull sentence structures…" He goes on to declare, "This vocabulary [of design drawing] needs to be expanded as does the vocabulary of any language that stays alive" (p. 111).

We live in a world, especially in academia, overshadowed by words. Lockard (1977) observed that, "Our cultural heritage is dominated by a linear, verbal, and 'rational' tradition which can inhibit the use of drawing in design." The implication of this tradition is a belief that decisions are made "rationally" (meaning in the mind verbally), and drawing is merely an act of the hand "printing" the decisions out. Instead, he argues for allowing the unconscious mind to contribute to the design process: "We are much older, and

perhaps much wiser than our mathematical, verbal, 'rational' left frontal lobes, and drawing is one of the most natural and direct outlets for this rich and mysterious resource."

Design Drawing as Design Language

One reason that design thinking and design drawing seem to be so similar is that drawing is very much like another closely related thinking activity: language. In fact, for most fields of design, we might agree with Archer (1992) who says that drawing is the language of design. Robbins (1994) also noted the similarity between drawing and language: "Because drawing is used to communicate ideas and to instruct others about a design, it is often seen as a language. Architects, when speaking about drawing, assume more often than not…that drawing may be construed to be a language or a quasi-linguistic order of communication" (pp. 27–28). Lockard (1977) says:

It is time we looked at drawing again, or perhaps for the first time, as a conscious activity, and a communicative language having, like any language, a syntactical structure. It is time we realized that the drawings we use, the order in which we choose to draw them, and our free, creative, confident use of, and continual, deliberate expansion of this language of drawing lie at the very base of any design method (p. 106).

Tversky (2002) has identified several attributes of drawings that are language-like. "[Design drawings] are segmented into elements. They consist of language-like strings of stylized figures, lines, curves, and blobs. These elements can be combined in different ways to create different meanings, again, like language."

Languages facilitate communication. Vygotsky (Vygotski & Kozulin, 1986) proposed that languages also facilitate thought. Simon (1996) identified some of the value of a design language to thought when he noted "By erecting such a hierarchy of concepts for himself, the designer is, after all, able to face the problem all at once. He achieves a powerful economy of thought, and can by this means thread his way through far more difficult problems than he could cope with otherwise." Languages in general provide advantages, particularly useful to design: (1) they allow thought to be communicated so that good ideas do not get lost; (2) they provide a focus of attention which permits higher-power processing and anchoring of thought; and, (3) they provide the ability to question and judge the value of a thought—to construct thoughts about thought (Jackendoff, 1996). Schatz (2003) has suggested that for the field of ID to grow, it needs a design language to communicate what works and what does not, as is the case in engineering. Gibbons and Rogers (2006) have argued for the need for more than one design language in order to express a design: "…many design languages already exist, and new design languages can be created that provide terms appropriate to the solution of sub-problems…"

Stages in Design and Design Drawing

Design takes place in stages, and changes in design drawing shadow these stages. The stages can be traced by observing to whom the drawing is intended to communicate, which is closely paralleled by the purposes for which they were drawn.

Designers in many fields often start their work with rough sketches to "try out" ideas before they commit them to more formal representations. "Engineers are notorious for not being able to think without making 'back-of-the-envelope' sketches of rough ideas. Sometimes these informal sketches serve to communicate a concept to a colleague, but more often, they just help the idea take shape on paper" (Ullman, Wood, & Craig, 1990).

As the design progresses to the latter purposes, the drawings become more formal, more governed

by rules and conventions. Bucciarelli (1994) differentiated between the "hastily rendered sketch made to assist in the story telling of the moment" characteristic of early design, and the more formal "graphics, mechanical assembly drawings, circuit topographies, block diagrams, and charts" that exemplify the formal representations used for later purposes of design.

The more formal the drawing, the more commitment on the part of the designer is implied. For obvious reasons, it is better to catch a flaw or make a change at the sketching or drafting stage, or even after a formal design model has been made, than after the product has been produced.

Lockard (1977) organizes the stages of design by identifying the person for whom the communication at each stage is intended, in this manner:

1. Self-communication
2. Inter-professional communication
3. Client communication
4. Builder communication
5. Public communication.

Because he is primarily writing for architects, Lockard uses the term "builder communication," but any communication to any production person would fit the described stage. Forms of communication, often design drawings, move through these stages as well.

The creative work of the designer starts with what Lockard (1977) calls "self-communication." McKim (1980) ties self-communication directly to sketching and calls it "graphic ideation": "Graphic ideation is visually talking to oneself; graphic communication is visually talking to others" (p. 135, italics in original). He divides the first, graphic ideation, into two kinds of activity:

Graphic ideation has two basic modes: exploratory and developmental…

In the exploratory mode of graphic ideation, thinking and sketching are adventurous…Each sketch captures general features only, not details; it is a kind of rough map that allows you to return later to the concept, if you choose to develop it further.In the developmental mode of graphic ideation, you…develop a more thorough understanding of a promising concept.

This division meshes with Lockard's (1977) original idea of self-communication, where the first, exploratory drawings are analytical in nature to help the designer see broad patterns. Later, developmental drawings are held up for comparison to design determinants to become tentative detailed solutions to the problem (p. 107). These two types of sketches are reflected in the two types of design cognition noted by Ulric Neisser, whom McKim (1980) quotes: "…all cognition consists of a two-stage act of construction: 'the first is fast, crude, wholistic, [sic] and parallel, while the second is deliberate, attentive, detailed, and sequential'" (pp. 147–148).

The earlier, exploratory stage is most closely associated with Simon's (1996) gap, mentioned above, in which design drawing serves as one bridge between the mind of the designer and the real world. McKim (1980) defines exploratory drawing as "a means of probing [the designer's own] imagination, seeking to touch and record the vague and elusive imagery that usually accompanies the conception of a new idea" (p. 134). Verstijnen et al. (1998, p. 520) point out that these exploratory idea-sketches have an important role in the creative process so often associated with design. It is to the exploratory process that McKim alludes when he says, "…drawing and thinking are frequently so simultaneous that the graphic image appears almost an organic extension of mental processes…Drawing not only helps to bring vague inner images into focus; it also provides a record of the advancing thought stream" (p. 11). Hanks and Belliston (1977) seem to be referring to exploratory design drawing when they say, "Since ideas and mental images are foggy, fleeting, and incomplete, it is imperative that they be captured and studied. Drawing is one way this can be done. Drawing allows you

to bring the idea to life. It allows you to change, judge, and evaluate your thoughts."

In the later, developmental drawing of the first stage, by contrast, the idea evolves through its embryonic concept into a mature form by repetition and refinement. McKim (1980) says "Developmental sketching is less schematic and more concerned with concrete details." The developmental phase is described by Arnheim (1995) as "a series of approximations, each one incorporating more relevant information and evolving until the final form emerges." McKim notes the memory-supporting facility of design drawing in his description of the developmental stage: "Drawing provides a capability that memory cannot: the most brilliant imager cannot compare a number of images, side by side in memory, as one can compare a wall of tacked-up idea-sketches." In fact, this developmental stage is where design may begin to be shared with other designers as per Lockard's second recipient-based stage: inter-professional communication.

As these drawings progress, they become less free and more formal, less vague and more concrete. At some point the drawings cease to be clarifications, and become proposals: attempts to convince or persuade others of their value. It is at this point that they move to the third stage of communication and beyond: client communication, builder communication, and public communication. "[A]ll further drawings become a persuasive device, 'commercials,' to inform and persuade [the designer's] professional associates, his client, builder and the general public that his design is the correct, reasonable, and beautiful solution to the problem" (Lockard, 1977). Once the client has been convinced (which Lockard says comes by compromise and negotiation) the design is "set" and the drawing "finished." The design drawings are used to communicate with builders (Robbins & Cullinan, 1994). The design has crystallized or "hardened" where it is unlikely to see major change. Finally, it may be used to communicate directly with the public. Robbins (1994) says that, for an architect, this form of design drawing often takes place after the building is built!

Later forms serve as the long-term memory of the design. Unfortunately, the earlier rough sketches "rarely survive for future generations to inspect" (Bucciarelli, 1994, p. 118). This is unfortunate because, as Lockard (1977) observes, that the importance of design drawings to the creative aspect of design dwindles as the drawing becomes more refined. In a book for aiding architects and designers he laments,

In surveying the drawings I have used to illustrate my ideas I find that they are all rather stiff, studied works… I have never habitually saved the first rough sketches precisely because they are only a means—their only value being an interim visual statement toward a final real building… Except for the need to communicate the architectural idea more formally to other people, the purpose of drawing the space is fulfilled with these little sketches.

Up to this point, we have used Lockard's stages to discuss stages in design and design drawing. These stages use the recipient of communication to identify the stages of design and design drawing. It will be our approach that the progression from stage one to two, from two to three, and so forth, are often indicated by a change in purpose, as much as a change in recipient. These changes in purpose do not map perfectly onto the changes in recipient, but clearly show the same progression:

1. Ideation,
2. Negotiation,
3. Persuasion,
4. Crystallization, and
5. Dissemination.

Both design and design drawing occur in stages that represent the recipients of communications, and also the purposes of communication. Lockard points out that the movement among these is not strictly linear. More often than not, the designer will cycle through previous stages as the design

takes form and shape. Earlier stages are gradually abandoned in these cycles as negotiation and persuasion are accomplished; the design crystallizes and the sketches become means of dissemination. The sketches become increasingly formal and set, more useful as communication than ideation.

CATEGORIZING DESIGN DRAWINGS BY FORM

Design drawings may be categorized by their form, that is, by their shape, as well as the purposes for which they are drawn. Four examinations of form are reviewed and the list of groupings described by the chapters in a book by Laseau's (1986) serve as the best characterization of a taxonomy of design drawings in the early, abstract stages of design. To this is added a category for representational graphics (after Massironi, 2002) to serve as a taxonomy of design graphics by form.

Simon (1996) observed that "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. This step has not yet been taken with respect to representations. We have only a sketchy and incomplete knowledge of the significance of the differences" (p. 133). This section will examine different kinds of abstract design drawings to formulate the beginnings of a taxonomy, based on form.

Massironi (2002) has specifically attempted to create a taxonomy to classify and identify various kinds of graphic representations (See Figure 1).

When considering design drawings, Massironi's most helpful contribution is his division between representational and non-representational figures—the two heavy horizontal lines in Figure

Figure 1. A taxonomy of graphic productions (Massironi, 2002, p. 3)

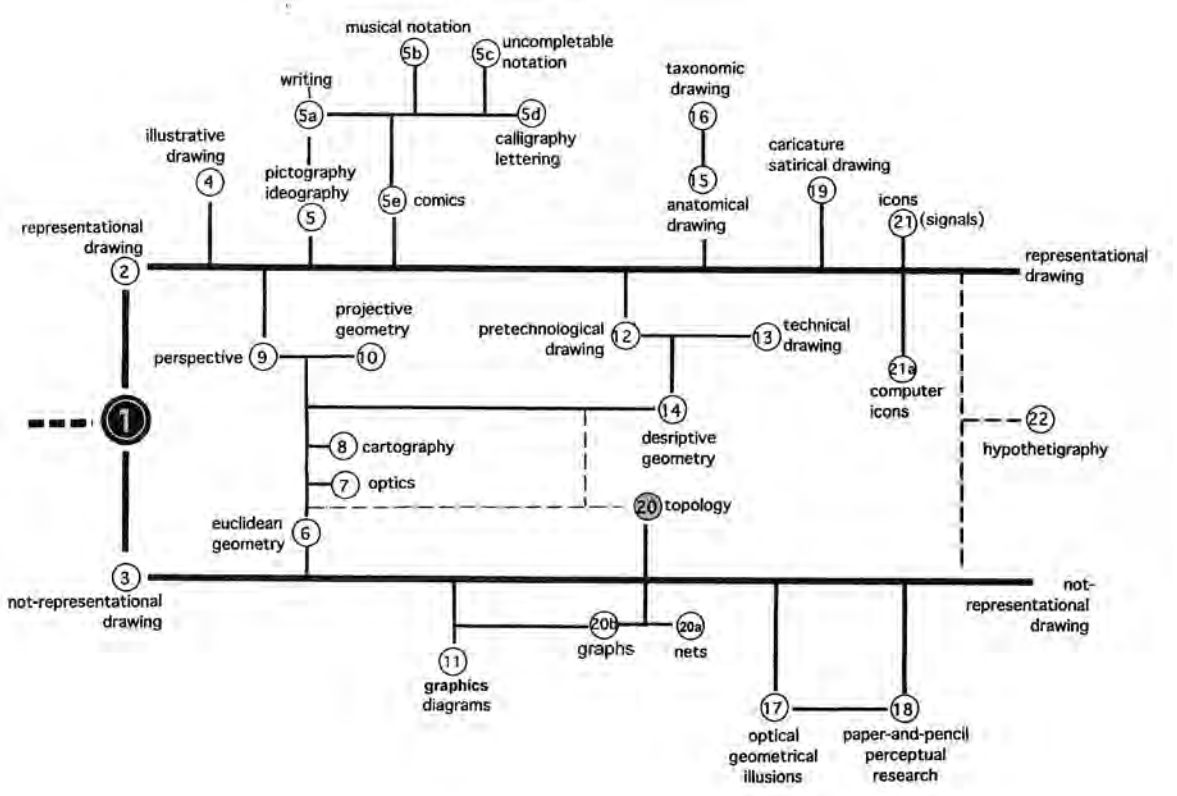
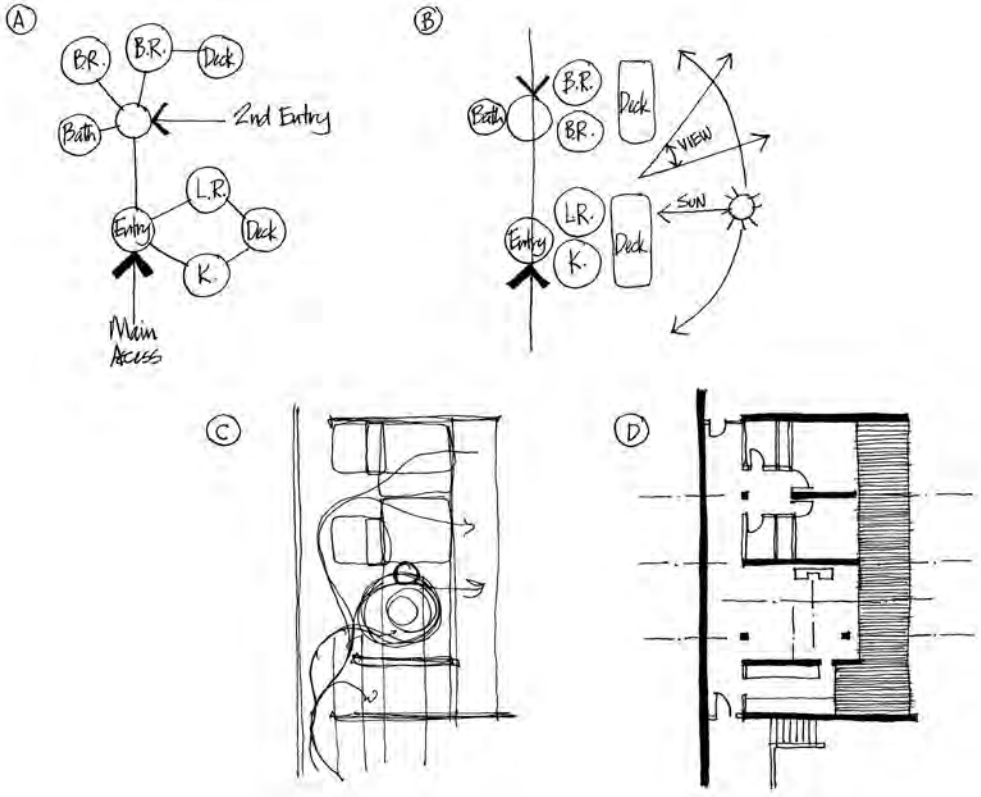


Figure 2. Progression from a bubble diagram (A) to architectural plan (D). (Laseau, 1975, pp. 28–29)

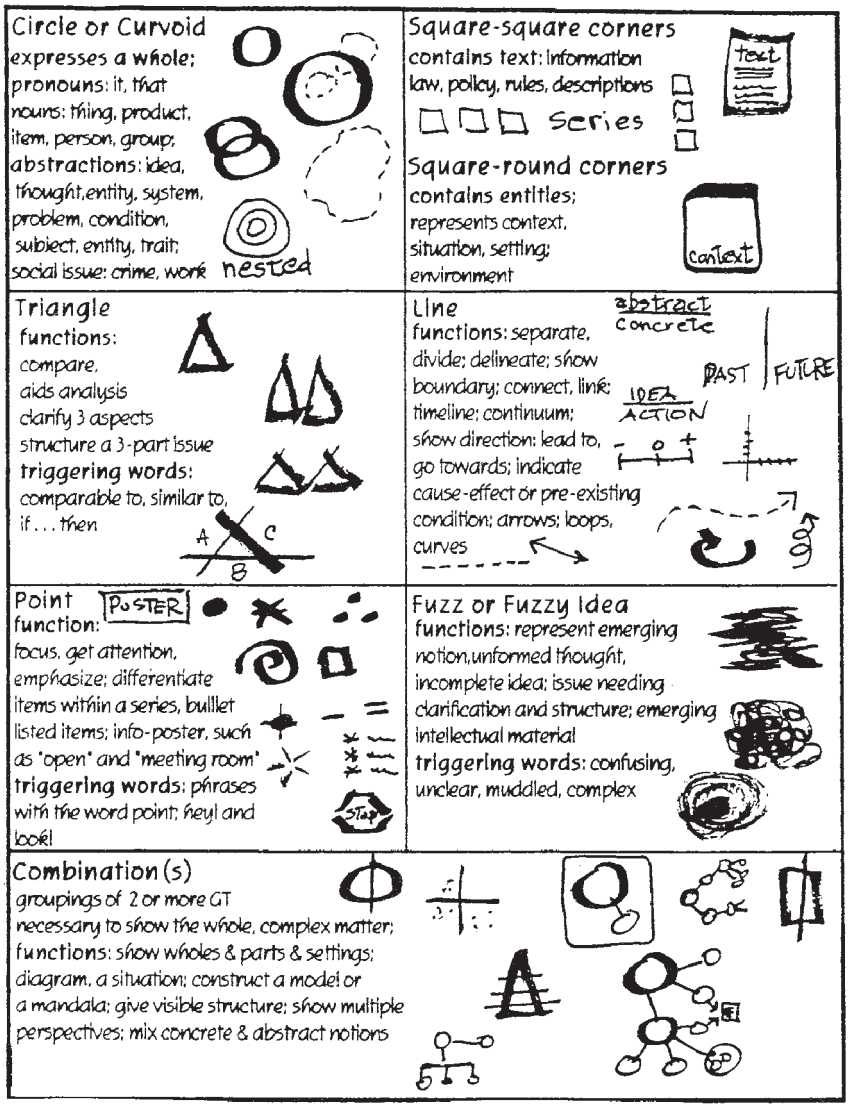


1. Many design drawings represent a physical reality, others are used to illustrate abstract concepts. As illustrated in Figure 2, the one may develop into the other. In this case, a conceptual bubble diagram evolves into a rough floor plan. Note that the diagram of Massironi (Figure 1) includes several types of drawing that lie between the two and are connected to both. Figure 2 shows how ideas in the form of a bubble diagram progress through stages to become a rough architectural plan. Development from that stage to a complete blueprint is not difficult to imagine. Concrete, and even fully representational drawings may begin their existence as loosely-drawn, abstract forms.

Hansen (1999) proposes a basic abstract drawing language built from the symbols found in Figure 3. A quick review of these symbols will reveal that many of them are common sense (such as using lines to separate or connect, and squares as containers). Hansen provides the primitives (the "words" or symbols) and only hints about the "grammar" that would allow their combination into meaningful expressions. In this simple illustration, Figure 3, Hansen has captured many of the important elements and ideas of the abstract side of design drawing.

In chapter 21 of his book *Thinking Visually*, McKim (1980) provides common examples of what he terms abstract graphic languages. While McKim did not set out to build a taxonomy, his set of examples is valuable because the types of diagrams he includes specifically serve design and planning, at the same time giving designers ideas of where and how to use them. Though the types identified are very specific, his treatment of them is liberal enough to include instances that may lie on the periphery of each type. He does

Figure 3. Hansen's "Graphic Tools"(Hansen, 1999, 193-220)



not imply that the list is in any way complete; on the contrary, you get the idea that this is just a sampler. His list includes the following types of abstract graphic languages:

1. Venn diagrams
2. Organization charts
3. Flow charts
4. Link-node diagrams
5. Bar charts and graphs
6. Schematic diagrams
7. Pattern languages (As per Alexander, 1979)

In a similar, book-length treatment, *Graphic problem solving for architects and designers*, Laseau (1986) condenses all types of abstract design graphics into four basic groups. These groups are inclusive of McKim's abstract graphic languages. Each of Laseau's categories is covered by a chapter, with lots of examples:

1. **Bubble diagrams:** Squares, circles and other shapes ("bubbles") are containers for concepts; lines and arrows between them as well as their overlap represent relationships among the bubbles. Organization charts and flow charts are examples of these.
2. **Area diagrams:** Like bubble diagrams, drawn shapes are containers, but in this case the area of the bubble is representative of some kind of size or importance. Venn diagrams are the most obvious of these, but bar charts and graphs also exhibit characteristics of this type.
3. **Matrices:** In a matrix, the horizontal and vertical positioning of elements represents meaning. It is a way to show complex relationships in two or more dimensions. Schematic diagrams are occasionally of this type, as are graphs and tables. A text outline may be a type of matrix.
4. **Networks:** Networks are essentially bubble diagrams where the arrows and lines take on more importance than the bubbles, forming complex maps of lines showing relationships. Link-node diagrams are clearly of this type, though organization charts and flow charts may also be.

The value of the list of Laseau's chapters, as summarized above, is that it includes the various forms of abstract representation (such as all of McKim's abstract graphic languages) and groups them into understandable categories according to common characteristics. If we add an item for concrete or representational graphics as well, (from Massironi's first division) Laseau list a good, basic system for organizing design graphics by form.

Value of Vagueness in Sketching

One of the advantages to abstract forms of representation is their ability to portray an appropriate level of ambiguity or vagueness—at least until the design has crystallized. The drawing must represent the current level of refinement, but not more. The sketch notates decisions made, while leaving ambiguous those areas of the design where decisions have not yet been made, leaving the door open for further refinement. Arnheim (1995) goes so far as to say that such a sketch, "…shows [its] vagueness with a desirable precision." This vagueness and ambiguity, according to Bucciarelli, not only enables design, but it is the very essence of design:

... a healthy measure of ambiguity and uncertainty makes room for designing... Participants envision and construe the uncertain as options, but behind the mask, the unknown lies waiting—and that too, is valued by participants. Uncertainty is what gives life to the design process and makes it the challenge that it is. If the process lacks uncertainty, then you can be sure it is not designing but copying (Bucciarelli, 1994, p. 177).

Tang and Vero (2001) empirically confirmed the importance of vagueness in design representations. They observed that:

...a depiction has more than one meaning graphically and semantically after being created. It carries groups of meanings and relationships. Designers utilize this characteristic to generate different concepts and to reason about functional issues through sketches. Consequently, sketches become affordances of meanings in the design process (p. 279).

These "affordances of meaning" make it possible that, even though sketches are made with certain ideas and goals in mind, designers may fortuitously "…see new objects and configurations in their sketches. These encounters produce welcome but unintended discoveries, and may be a fruitful source of new design ideas" (Tversky, 2002).

Arnheim believes the vagueness of the sketch accurately reflects the ambiguity in the related mental image. He casts this vagueness as a plus, because, "…it has the positive quality of a topological shape. As distinguished from geometrical shapes, a topological shape stands for a whole range of possibilities without being tangibly committed to any one of them. Being undefined in its specifics, it admits distortions and deviations... This same vagueness is frequently apparent in the designer's sketches" (p. 71-72).

Design as Ill-Defined Problems.

This ambiguousness in both the sketch and the mental image reflects the way designers tend to think about design problems in general. From the earliest cognitive studies of design (Eastman, 1969), to the present, design has been thought of as a process of solving of ill-defined problems. Cross (2001) declares, "It is widely accepted that design 'problems' can only be regarded as a version of ill-defined problems." (Design has also been called a wicked problem [Rittel & Webber, 1973], which is an expansion of the term *ill-defined*.)

Though the term ill-defined is described in various ways (Newell & Simon, 1972; Reitman, 1965; Zimring & Craig, 2001), what most definitions have in common is that ill-defined problems have "variable problem spaces" (Zimring & Craig, 2001), meaning that these problems require constant restructuring to arrive at a solution. Unlike well-defined problems, where the solutions can be obtained by reduction, transformation, or optimization of the data in the requirements (Archer & Roberts, 1992), ill-defined problems resist these systematic approaches to being solved, or are at least approached as though that were the case. In ill-defined problems, both the problem and the solution are moving targets, and solution and problem co-evolve in relation to each other (Dorst & Cross, 1996).

This is interesting in light of what Simon (1996) says about solutions to problems being found in their representations of whatever form:

All mathematics exhibits in its conclusions only what is already implicit in its premises...Hence all mathematical derivation can be viewed simply as change in representation, making evident what was previously true but obscure.
This view can be extended to all problem solving—solving a problem simply means representing it so as to make the solution transparent. If the problem solving could actually be organized in these terms, the issue of representation would indeed become central. But even if it cannot—if this is too exaggerated a view—a deeper understanding of how representations are created and how they contribute to the solution of problems will be come an essential component in the future theory of design (p. 132).

Simon's speculation certainly seems to hold true for well-defined problems like those of mathematics, but what if the problems are ill-defined, like design problems are characterized to be? What would then appear to be needed is a mode of representation that is capable of leaving undefined those portions of the design concept that have yet to crystallize while at the same time representing clearly what has crystallized. Sketching in the hands of a skilled designer would seem to meet this requirement.

Another aspect of ill-defined problems and design is that designers, especially expert ones, tend to treat all problems as though they were ill-defined, even when those problems are well enough defined that they might reasonably respond to analysis. Cross (2001) observed that "designers will be designers, even when they could be problem solvers": they tend to approach all problems as though they were ill-defined, as though the problem was as negotiable as the solution. More specifically, designers tend to start off quickly with proposed solutions, however rough they may be, and refine them as they proceed, rather

than analyzing the data thoroughly in order to formulate a solution:

Many studies suggest that designers move rapidly to early solution conjectures, and use these conjectures as a way of exploring and defining problem-and-solution together. This is not a strategy employed by all problem-solvers, many of whom attempt to define or understand the problem fully before making solution attempts. This difference was observed by Lawson (1979), in his experiments on problem solving behavior in which he compared scientists with architects: '...[The scientists] operated what might be called a problem-focusing strategy... architects by contrast adopted a solution-focusing strategy'(Cross, 2001, p. 83).

In many cases design representations—usually sketches and drawings—fill the role Simon suggests, to make the solution transparent. According to Lockard (1977):

In the design process, we need to display tentative design proposals which we can continually compare to the restated design problem. These graphic representations will suggest restatements of the problem, and those restatements will in turn suggest more drawings (p. 10).

Then, it is back to the drawing board (literally!) to modify the proposed sketch to reflect a new understanding of the problem and the solution—in a repeating cycle that results in constantly more refined drawings, and problems. This cycle between what is and what should or could be, as it applies to the representations, has been referred to as "the dialectic of sketching" (Goldschmidt, 1991).

THE DIALECTIC OF SKETCHING

In her much-cited study about the dialectic of sketching, Goldschmidt (1991) first breaks down design thinking into observable units which she calls *movements*. She observed that progress in the design alternated between one type of seeing to another and back again through these movements. These two types of seeing each support a different type of thinking. One type is analog or metaphorical thought which deals with seeing new meanings in the sketch. She calls this *seeing as*. Creativity is provoked in this reinterpreting of the sketch. The other type of thinking deals with the consequences of the newly perceived meanings—of judgment—which Goldschmidt called *seeing that*.

The importance of Goldschmidt's study is that she observed empirically a phenomenon which has been proposed by others in theory or self-reporting (See, for example, Lockard, 1977; and McKim, 1980). Verstijnen et al.(1998), also observed a dialog, between combining and restructuring of concepts which could be viewed as virtually the same dialectic from a different perspective.

It is Arnheim's (1995) opinion that without drawing, the dialectic that Goldschmidt observed does not happen; and without the dialectic, design does not happen; ergo, drawing is essential to design.

Drawing & Narrative

As important as drawing may be to the design process, it rarely stands alone. Design drawings are nearly always accompanied by narrative, which supplements and adds meaning to the image. Bruner (2003) has stated, "We organize our experience and our memory of human happenings mainly in the form of narrative—stories, excuses, myths, reasons for doing and not doing, and so on" (p. 44). Visual representations, on the other hand, "…can render phenomena, relationships, and ideas visible, allowing patterns to emerge from apparent disorder to become detectable, and available, to our senses and intellect" (Hansen, 1999, p. 198). The two, together, are better at communicating than either is alone.

McCloud (1993) has observed that while, historically, pictures and words have become separate entities in modern culture, they are actually exist together in a larger continuum. He argues that it is their natural state to be mixed together (as indicated in the name of the Kindergarten activity, "Show and Tell.") He elaborates, "Words and pictures are like partners in a dance and each one takes turns leading…. When these partners each know their roles and support each other strengths…" they are powerful.

Bucciarelli observed the important relationship between narrative and drawing:

Drawings…show the characteristics displayed in narratives and, indeed, are themselves essential to narrative [italics added]. They show hierarchy, are abstract, bounded, measured, and so on. These are not just characteristics of the formal drawings stored and saved for posterity…but they also structure the hastily rendered sketch made to assist in the story telling of the moment (p. 118).

Schön's (1987) protocol studies of architectural students makes visible the kind of dialogue that occurs between designers and their designs (as well as among designers). These dialogues show that neither the narratives nor the design drawings would be completely comprehensible without the other. Another example can be found in motion pictures' use of narrative and the storyboard. A storyboard is nearly always accompanied (at a minimum) by snippets of the script written under the drawings, or in some cases, full impromptu performances used to complete the conveyance of the information in the drawing (See Hart, 1999).

The narrative associated with design drawing may be text found in the diagram itself (such as labels in boxes, etc.), it may be written nearby (as captions or explanations) or in may be from spoken words (in performance). Regardless of their relative location, words and stories—narrative—often accompany design sketches. These narratives complete and supplement the design drawings, and are, in fact, essential parts of fulfilling the purposes of design drawings.

Drawing as a Catalyst for Social Agreement/Commitment

One thing that makes the combination of words and graphics powerful is their ability to engage others in the act of design. Some have romanticized design in to a solitary act, shared only after it is perfected by the designer (Lockard, 1977). But, as already noted, design and design sketches go through stages of negotiation and persuasion with others: other designers, clients, patrons, builders, collaborators, etc. If they are focused on common goals and outcomes, drawing serves as an important catalyst to draw these people together, or at least give them a common focus of discussion.

Bucciarelli's (1994) ethnographic study of design engineering situations observed that, "Despite differences among individual interpretations and constructions…participants do communicate, negotiate, and compromise; in short, they design" (p. 81). Later, he concludes:

Shared vision' is the key phrase: The design is the shared vision, and the shared vision is the design. Some of this shared vision is made explicit in documents, texts, and artifacts—in formal assembly and detail drawings, operation and service manuals, contractual disclaimers, production schedules, marketing copy, test plans, parts lists, procurement orders, mock-ups, and prototypes….The shared vision, as some synthetic representation of the artifact as a whole, is not in the documents or written plans [emphasis ours]. To the extend that it exists as a whole, it is a social construction—dynamic, plastic, given nuance and new meaning at each information gathering of two and three in a hallway or at formal meetings such as scheduled design reviews (p. 159).

As he notes in another place, "The final chart is hardly interesting, and rarely referred to, unless it later shows a bug or is challenged by further developments. But if that happens, the negotiation process starts anew" (p. 189). This view is reflected by Robbins (1994, p. 29) where he says, "Drawing and the worlds it represents are a product of social and cultural agreements among architects and others."

Final design drawings and documentation serve as the long-term memory of the design and show commitment. These documents are required to stand on their own in spite of the fact that only those who participated in the negotiation that resulted in this design will be able to derive the full context and meaning from them. They become reference works to which the designers and producers refer. Formalization and crystallization are intended to strengthen and solidify the documents as tools of communication, but it requires careful skill to weave the meaning into these reductions in order for them to convey that meaning through the artifact.

SUMMARY OF RESEARCH ON DESIGN DRAWING IN DESIGN STUDIES

In summary, we have observed that designers in most design fields accomplish their work by means of design representations, of which design drawing is an important type. As noted, the basis of design drawing's importance in those fields lies in its flexibility and power for creating design representations. This flexibility and power is due to a number of characteristics of which make it appealing to designers, including its ability to represent design thinking, its language-like characteristics, and the fact that it can represent all stages of design with a number of expressive forms. Design drawing also has the advantage of being appropriately vague when a vague representation is needed to further the design, or concrete when a concrete representation is needed. This flexibility makes it well suited for working with ill-defined problems—like design. Without "the dialectic of sketching," some authors believe that design itself is in jeopardy. Drawing is often accompanied by some kind of narrative, to act as an artifact for a shared vision of the design—which identifies the true locus of design, in the minds of the creators.

CONCLUSION

This brief review of the many uses and roles of design drawing in fields outside of ID as demonstrated in the literature of design studies. It illustrates the depth of interest that this topic has in that literature. With both a long history and deep connections to practice, design drawing is a staple of most design fields. Unfortunately, that is not the case with ID. As we have shown elsewhere (see Chapter XVII) design drawing in ID lags behind most other fields in exploiting the value of design drawing for designing.

We began this chapter by discussing the similarities between ID and other fields of design. Given these similarities, and the reliance of these other fields on this basic method, ID practitioners would be wise to consider the characteristics of design drawing as they develop and use VIDLs. These characteristics go to the very heart of what makes a VIDL useful to the design process.

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ENDNOTE

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Theories and Practices

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