Title
Immersion in Early Architectural Design in the Age of Computing

Author
Date, Kartikeya

Publication Date
2018

Peer reviewed|Thesis/dissertation

Immersion in Early Architectural Design in the Age of Computing

By

Kartikeya Anil Date

A dissertation submitted in partial satisfaction of the

requirements for the degree of

Doctor of Philosophy

in

Architecture

in the

Graduate Division

of the

University of California, Berkeley

Committee in charge:

Professor Yehuda E. Kalay, Chair
Professor Andrew Shanken
Professor Whitney Davis

Summer 2018

Abstract

Immersion in Early Architectural Design in the Age of Computing

by

Kartikeya Anil Date

Doctor of Philosophy in Architecture

University of California, Berkeley

Professor Yehuda E. Kalay, Chair

This dissertation proposes a concept of immersion as an integral aspect of a general theory of the (early phase) architectural design act in the age of computing. Computing has influenced design in two major ways – as a metaphor shaping contemporary understanding of the design process, and as a machine used in the practice. The history of the relationship between these two modes of influence is traced to locate immersion in a model of the architectural design process. Early design is explored in this study by a comparative study of design across variously technologically mediated sketching environments. This process is considered as an individual process. Collaborative design is set aside.

Computing has influenced design in two ways – as a metaphor for the process and as a machine used in the process. These two types of influences could also be understood to define two distinct tracks along which research in computer aided design has been developed. As a machine, computing has been studied in the fields like evaluation simulations in various domains such as acoustics, energy consumption, structural analysis, emergency evacuations, generative models, and representational models. Research in the broad field of design and computing can also be understood to have developed along these two tracks. Sketching has emerged as the predominant mode of interest to scholars who study design as a cognitive activity.

Recent technological developments in the field of computational support to augment sketching, which is an important representational mode in early design, enable designers to sketch immersively 'at the site'. The significance of this technological advancement, which makes the site available to the designer/architect at human scale, to architectural representation, especially in the early design process, remains poorly understood. This new capacity for immersive sketching is used as a starting point for developing the concept of immersion in architectural design. The Hybrid Ideation Space (HIS), an immersive sketching environment developed in the Industrial Design faculty at the University of Montreal by Prof. Tomas Dorta and his colleagues is used.

Hitherto, much of the scholarship has been focused on the study of design (as a process) and sketching (as a practice). Immersion has been understood as a property of the technology used during designing. Presence, a related but distinct idea has been understood as a property of the user (or in this case, designer). An examination of the technological context of the HIS and the theoretical context of scholarship of design as a process and as a mediated practice, it is argued that immersion is not strictly a geometrical or spatial idea, or a property of the technology, but exists at the intersection of a three-way relationship between designer, design representation and

design context.

A concept of immersion as an aspect of designing is developed in this thesis through a combination of theoretical inquiry and empirical, exploratory comparative case studies involving a conceptual design problem made available to participants in three different mediated design environments – sketching at the site, sketching in the HIS, and sketching based on a set of photographs of the site. This work sets the stage for narrower, quantitative experimental work which could further refine and detail the proposed concept of immersion, enable cross-media analysis of designing and contribute to the understanding of design as a systematic, purposeful activity.

Table of Contents

List of Figures

Acknowledgements

The debts I have accrued during this dissertation are many. The debts I acknowledge here are but a few of the nearest ones.

I would like to thank my supervisor Prof. Yehuda Kalay for his guidance and patient advice throughout my time with him, first at Berkeley and then at the Technion in Haifa, Israel. I am indebted to him intellectually for shaping my understanding of the relationship between computation and design. I have also learnt from his fine example as a mentor and a teacher in the traditional classroom and in research settings.

I would like to thank Prof. Andrew Shanken who has been a kind and supportive advisor throughout my time at Berkeley. I am especially grateful for his detailed comments on drafts. Prof. Whitney Davis's supervision in the history and theory of visual representation has been crucial to my understanding of architectural representation.

I thank Prof. Tomas Dorta and his students at the University of Montreal for allowing me to use their experimental sketching environment in my dissertation work. I am especially grateful to my friend Gokce Kinayoglu for his kind assistance when I visited Montreal. Annemarie Lesage, Edgar Perez came to Berkeley as part of their doctoral work with Prof. Dorta to install HIS at Wurster Hall.

I had the opportunity to teach the introductory environmental design course at Berkeley with Prof. Nicholas de Monchaux and Prof. Linda Jewell. The example of their wonderfully distinctive approaches to teaching has informed the development of my understanding of teaching.

I would like to thank my friends and colleagues in the Digital Design Research Group at Berkeley, and Prof. Kalay's Event Simulation Lab at the Technion for their friendship and collegiality over the years. I have learnt from their varied and interesting projects and the diligence and excellence with which they have pursued them. I have enjoyed my intellectual discussions with my friends Seungwan Hong, Cecilia Chu, Yael Allweil, Tiago Castela, Lusi Morhayim and Ipek Tureli.

I had the opportunity to stay at International House during my time at Berkeley. I thank the many friends I made there for their companionship and long, involved discussions at the dinner table.

I thank Lois Koch in the graduate office for her guidance in all things official.

Finally, I thank my parents and my sister for their patient support and endurance as I pursued this dissertation. The example of my parents and the inspiration of my sister have informed my life.

1. Introduction

Statement of the Problem

In the field of design theories and methods (DTM), design is understood as a purposeful activity which involves the transformation of an existing situation into a preferred situation. Efforts to develop a systematic understanding of design since World War II have been significantly influenced by the emergence of the computer. Computing appears in design, first as a metaphor influencing its theorization, and then as a machine influencing its practice. Efforts to develop a systematic theory of design have been set aside in recent years in favor of focused efforts to understand the role of computing in more specific processes such as representation, generation, evaluation of design proposals and augmentation of representation systems.[1] Design itself has comes to be understood as a heterogenous practice rather than a systematic process or method.[2] This way of understanding of design has implications for the way in which new technologies are understood as a part of the design process.

In this thesis design is defined as a mediated, systematic activity which may involve one or more media whose purpose is to assist representation, analysis, evaluation or communication of design ideas, proposals, or issues which may be of relevance to the problem at hand. Specifying design as a process involves describing the structure of the process and explaining how designing proceeds within this structure. Specifying design as a heterogenous practice involves the implicit claim that there is no common underlying structure to design. The involvement of different mediating technologies in different types of design problems means that meaningfully describing a common process is difficult. Currently, the latter view holds sway in the discourse about theory of design. The implication of this view is that it is difficult to examine the effect of new technologies as they become available to designers. More importantly, it is also difficult to imagine what an improvement in technology available to designers might look like. Designers risk becoming consumers of technology rather than users.

With the advent of personal computers, the internet and numerous derivative advancements in graphics and analysis, the technological assistance available to designers has advanced at an accelerated rate. The historian of technology Antoine Picon argues that this has given rise to a new 'digital culture' in architectural design.[3] Additionally, technological advancement is influencing the built environment itself. This aspect of the influence of technology on buildings themselves is set aside. The problem at hand is concerned with developing a model of design, especially in the early stages of the process, which may be applied in different mediated contexts.

Recent technological developments enable architects/designers[4] to be 'immersed' in the

---

[1] See Yehuda E. Kalay, *Architecture's New Media* (Cambridge, Massachusetts: MIT Press, 2004). The term 'design' is used in many sub-fields of scholarship in the broad areas of architecture and planning. The term is used here in the context of its definition in the field of design theories and methods, and broadly, in the consideration of design as a cognitive activity. Design theories and methods has been concerned with the understanding design as a systematic process and the role of computation in this process remains a central area of concern in the field.

[2] For an example of this view, see Dana Cuff, *Architecture: The Story of a Practice* (The MIT Press, 1992).

[3] Antoine Picon, *Digital Culture in Architecture: An Introduction for Thedesign Professions* (Boston, MA: Birkhaeuser, 2010).

[4] The terms 'architect' and 'designer' can be understood interchangeably unless otherwise specified.

site and sketch design proposals while immersed. These systems allow designer to be 'in the sketch'. These sketching systems make the site available to the designer statically at human scale. The general concepts of immersion and presence are used here, have been defined in human-computer interaction and virtuality scholarship. Broadly, immersion is considered a property of the technology, while presence is considered a property of the user.[5] In the present work, these are complicated by the fact that designers not only need to be immersed in the site, but they do so to conceptualize and imagining a transformation of the site (and not just manipulating objects which are already available at the site). This fundamentally affects the nature of the illusory shift in point of view which constitutes presence. It also affects the sense in which the affordance of the technology to enable immersion can be understood. A design-specific idea of immersion is required to account for this new technological capability. Further, this capability needs to be situated within a broader model of design.

Structure of the Thesis

This thesis is organized broadly in two parts. The first part (chapters 2, 3) involves a theoretical synthesis of selected scholarship in the field of design theory, theories of cognition, and human-computer-interaction (or technological mediation generally considered) over the last fifty years. The purpose of this theoretical synthesis is not only to trace the development of scholarly understanding of design, but also to locate the divergences which produced the two distinct strands of design theory which exist today – a dormant strand considering design as a systematic process, and a second strand considering design as a heterodox practice.

The second part of this thesis (chapter 4) discusses the Hybrid Ideation Space (HIS), an immersive sketching environment developed at the University of Montreal by Prof. Tomas Dorta and his colleagues in the Industrial Design faculty. This environment enables uses to "be in the sketch" as they prepare it by providing a real-time projection of the sketch on to a hemispherical screen. This technology provides designers with two simultaneous pictures (which are updated instantly in real time) of their sketch. The first is on the tablet screen which they use to make marks to add to or modify the sketch. The second is the projection of the sketch on the hemispherical screen which surrounds them as they work at the tablet.

A comparative case study is described in the second part of the thesis which involves advanced graduate students at Berkeley and Montreal working on a conceptual design problem in three distinct media – using sketching at the site itself, in a picture of the site in HIS, and using a set of photographs of the site (but no floor plans). This three-way comparison is designed to be exploratory. These case studies are discussed in detail in Chapter 5. Transcripts of descriptions of design solutions produced by participants are attached in the Appendix at the end of this document.

The concluding section of this chapter attempts to situate the idea of design in the larger discourse about design in the 20th century. Design is a common term in architecture and its related fields and as such, is overloaded with meaning. The following background seeks to locate

[5] For a review of definitions of the concepts of immersion and presence, see Mel Slater and Sylvia Wilbur, "A Framework for Immersive Virtual Environments (FIVE): Speculations on the Role of Presence in Virtual Environments," *Presence: Teleoperators and Virtual Environments* 6, no. 6 (1997): 603–16; Mel Slater, "Immersion and the Illusion of Presence in Virtual Reality," *British Journal of Psychology* 109, no. 3 (2018); WA Ijsselsteijn and G. Riva, "Being There: The Experience of Presence in Mediated Environments," *EMERGING COMMUNICATION* 5 (2003): 3–16.

the term in its current context. Further, this section also provides a broad overview of this dissertation.

Background and overview of the argument

The architect as a professional in a form that we might recognize today is canonically understood to have come into being in Europe in the 14^{th} and 15^{th} centuries when twin developments in printing technology and drawing technique changed the way knowledge about buildings could be developed, stored and disseminated.[6] This advancement enabled architects to conceptualize buildings in their entirety away from the building site before any work was done at the site itself. Orthogonal, perspective and axonometric drawings, scale models, parametric models, generative algorithms and other modes and systems of representing architectural designs have emerged in the last 500 years. These constitute a history of the ways of organizing architectural knowledge.[7]

A more recent development with a shorter history is concerned with the effort to systematize and tame the process of design itself. The ability to conceptualize buildings and built environments away from the building site, allied with the development of ever more complicated industrial, economic and political processes meant the building programs became increasingly complicated, as did the ways in which the relations between the building and the environment were examined. The impulse to understand these processes systematically has been traced back at least to Viollet-le-Duc in the late 19^{th} century.[8] These theories of design have emerged separately from accounts of the history of architectural representation and demonstrate different attitudes to the importance of architectural representations. This thesis is concerned broadly with the relationship between theories of design as a process, and theories of systems of architectural representation and the relationship between the two.

Several prominent theories of design have been proposed in the last century. These theories broadly belong to what Jean-Pierre Protzen and David Harris call the "activist" and

---

[6] See Mario Carpo, Architecture in the Age of Printing: Orality, Writing, Typography, and Printed Images in the History of Architectural Theory (The MIT Press, 2001). for an account of the effect of printing technology on the dissemination of classical architectural theory. Also see Alberto Perez-Gomez and Louise Pelletier, Architectural Representation and the Perspective Hinge, 1st ed. (The MIT Press, 2000). for a broader historical argument about the consequences of the way in which architectural representation has instrumentalized the conception of the built environment. For evidence that complicates such a clear historical demarcation, see Spiro Kostof, The Architect: Chapters in the History of the Profession, 1st ed. (University of California Press, 2000)., and Stephen Parcell, Four Historical Definitions of Architecture (McGill-Queen's Press - MQUP, 2012). Both Parcell and Kostof hold the view that the architectural profession has gone through cycles, oscillating roughly between being an intellectual pursuit that required a liberal education and an empirical skill that could be learned only through apprenticeship. The argument made here is the much narrower one that depends on the possibility (through the availability of material and techniques) of designing buildings entirely away from the building site before any ground is broken at the site.

[7] For recent accounts of axonometry, diagrams and computer aided design, see Massimo Scolari, Oblique Drawing: a History of Anti-perspective, Writing Architecture Series (Cambridge, Mass: MIT Press, 2012).Mark Garcia, Diagrams of Architecture: AD Reader (Wiley, 2010). and Yehuda E. Kalay, Architecture's New Media (Cambridge, Massachusetts: MIT Press, 2004). respectively. For an account of the development of discursive aspects of the profession, see Hyungmin Pai, The Portfolio and the Diagram: Architecture, Discourse, and Modernity in America (The MIT Press, 2006). and George Barnett Johnston, Drafting Culture: A Social History of Architectural Graphic Standards (The MIT Press, 2008). in the American context.

[8] Tom Heath traced the need to find a method back to Viollet-le-Duc's view on the problem of abundance of knowledge and material wealth, Tom Heath, Method in Architecture (Chichester [West Sussex] ; New York: Wiley, 1984), 13.

“reflective” phases.[9] It is not the purpose of the current work to provide an exhaustive history of theories of design. Such accounts are already available.[10] Theories of design are considered with specific attention to their attitudes to designing as a mediated activity – as something people do in the world with some technological assistance (be it mechanical or electronic). Special attention is given to the development of these theories since the advent of modern computing in the lead up to World War II. It is proposed that the computer appears in theories of designing first as a generative metaphor, and then as a technological medium. Any useful theories of designing must acknowledge both these roles of the computer in the way design is understood and practiced.

Prior to the involvement of the computer in theories of designing, the understanding of design was characterized by mysticism (if the understanding purported to be holistic) and contingency.[11] The star practitioners of design defined what it was, and the discourse about design theory predominantly considered their view. For example, in Louis Kahn’s view, “A great building must begin with the unmeasurable, must go through measurable means when it is being designed and, in the end, must be unmeasurable”. “Form” for Kahn was about the immeasurable question, ‘what’, while “Design”, was about the measurable question ‘how’. Design for Kahn was a circumstantial act, contingent on realities like budgets, sites, available material, skilled craftsmanship etc., but this was not enough in and of itself to account for the work of the architect as a ‘conceiver of buildings’.[12] Kahn’s view of design and its limits illustrates a persistent effort within architectural practice and pedagogy to retain some mysticism about architectural designing.

Scholarship in DTM is engaged in developing a systematic understanding of ‘design’ as a creative human activity which can then be taught and developed further – in short, to demystify designing by systematizing its processes and methods. The computer as a metaphor for systematic activity sustained the field of DTM for nearly a decade in the 1960s. Several models of design have been developed in the course of over half a century of research under the DTM banner. However, the history of design methods precedes DTM. The approach to design in the Bauhaus, with the influences from the philosophy of the Vienna School may be considered precursors to the DTM era in design theory. It is an approach which influences the education of designers to this day, and with its atomistic construction of the contents of designing and attempts to develop a pedagogy for designing, is an important early example of a computationalist approach to design.[13] The classic approach in DTM – design as an information

[9] This is available in Jean-Pierre Protzen and David J. Harris, The Universe of Design: Horst Rittel’s Theories of Design and Planning, 1st ed. (Routledge, 2010).

[10] In addition to the work of Protzen and Harris, see N. Bayazit, “Investigating Design: A Review of Forty Years of Design Research,” Design Issues 20, no. 1 (2004): 16–29., and Nigel Cross, ed., Developments in Design Methodology (John Wiley & Sons Inc, 1984), 303–349.

[11] Systematic approaches to making buildings have existing for at least 2000 years, as is evident from the classical orders. The discussion here is focused on the understanding of the design process itself, rather than the existence of a set of rules for produces good buildings.

[12] Louis I. Kahn, “Form and Design,” Architectural Design 31 (1961): 145–154. This is the “definitive version” according to Robert Twombly. Kahn tended to give talks and develop them as he gave them again and again. See Twombly’s introduction in Robert C. Twombly, ed., Louis Kahn: Essential Texts, 1st ed (New York: W.W. Norton, 2003), 62. The phrase ‘conceiver of buildings’ is by Spiro Kostof in Kostof, The Architect.

[13] Computationalism refers to the approach that adheres to the principles of the universal Turing machine. The universal Turing machine was proposed by the mathematician Alan Turing in 1936. He described an abstract digital computing machine consisting of a limitless memory and a scanner that moves back and forth through the memory,

processing activity – dominated the first phase of history of DTM. This set of approaches has been variously described as the “activist” phase and the “first generation” approach.[14] The second set of approaches to DTM emerged in response to the perceived shortcomings of the first-generation approaches. These responses emerged from a variety of standpoints in practice and in theoretical scholarship. Theoretical developments in DTM relied on contemporaneous developments in cognitive theories of thinking and perception. The history of these theories is deeply significant to understanding the development of DTM. The computer emerged as the ubiquitous machine of designing alongside these theoretical developments.

In the period following World War II, the emergence of computing provided the possibility of modeling human thought itself as a mathematical process. Allen Newell, Herbert Simon and their colleagues were able to show that computers could play chess, solve theorems and perform other tasks which involved thinking. This, they argued, showed that it was clear that thinking could be modeled mathematically.[15] Following the work of Newell and Simon, scholars proposed computational bases for visual perception as well as high level cognition.[16] This early enthusiasm produced optimism about the possibility of describing complex problems systematically and producing solutions to these problems through a rational process. It also drew significant scrutiny and strong criticism from philosophers from different standpoints. John Searle proposed a thought experiment, which came to be known as the Chinese Room, in which he showed that the mere capacity to process symbols does not constitute a necessary and sufficient model of an understanding mind.[17] Hubert Dreyfus had earlier argued based on the work of Maurice Merleau-Ponty, Martin Heidegger and the later Wittgenstein[18], that our embodied presence in the world precedes our ability to make sense of it, and thus intelligence does not exist independent of a purpose and consequently, a situational context. Context cannot be broken down into discrete elements.[19]

---

symbol by symbol, reading what it finds and writing further symbols. Reading and writing is dictated by a program of instructions which is stored in the machine’s memory. Turing’s machine was universal, because, as he argued in a public lecture in London in 1947, it would be a machine that would learn from experience. The mechanism by which it would be able to do so, was the interaction between the program in memory and the input on the limitless memory. In 2013 this is now close to common knowledge, but for a compilation of Alan Turing’s work, see Alan M Turing, *The Essential Turing: Seminal Writings in Computing, Logic, Philosophy, Artificial Intelligence, and Artificial Life, Plus the Secrets of Enigma*, ed. B. Jack Copeland (Oxford : New York: Clarendon Press ; Oxford UniversityPress, 2004).

[14] Horst W. J. Rittel, “On the Planning Crisis: Systems Analysis of the First and Second Generations,” *Bedrifsokonomen* 8 (1972): 390–96; Jean-Pierre Protzen and David J. Harris, *The Universe of Design: Horst Rittel’s Theories of Design and Planning*, 1st ed. (Routledge, 2010).

[15] Allen Newell and H. A. Simon, “Computer Simulation of Human Thinking and Problem Solving” (Santa Monica, California: The RAND Corporation, 1961).

[16] David Marr, *Vision: A Computational Investigation into the Human Representation and Processing of Visual Information* (W. H. Freeman, 1983); James Jerome Gibson, *The Ecological Approach to Visual Perception* (Houghton Mifflin, 1979).

[17] See John R. Searle, “Minds, Brains, and Programs,” Behavioral and Brain Sciences 3, no. 03 (1980): 417–424.

[18] The “later Wittgenstein” refers to the philosopher Ludwig Wittgenstein’s work leading up to and including Philosophical Investigations published in 1953. This work involved a repudiation of his earlier Tractatus Logico Philosophicus in which he proposed, in the tradition of atomistic rationalism that the world was made up of facts.

[19] Dreyfus first presented his critique in Hubert L. Dreyfus, Alchemy and Artificial Intelligence (RAND Corporation, 1965)., and Hubert L. Dreyfus, “Why Computers Must Have Bodies in Order to Be Intelligent,” The Review of Metaphysics 21, no. 1 (1967): 13–32. which he later expanded into an influential book titled What Computers Can’t Do in 1972. He later developed a theory of expertise in Hubert L. Dreyfus and Stuart E. Dreyfus,

The breadth and depth of these criticisms led to advances in the field of cognitive science. The first generation understanding of cognitive science, known as "standard cognitive science" held that cognitive activity (what Newell and Simon called 'thinking') could be described mathematically as a symbolic information processing action.[20] Three broad responses to this idea emerged on the basis (in part) of the criticisms described above. Together, these three responses could be taken to mean that cognition is a situated process. First, it was shown that cognition is not dependent only on the symbol processing capacity of the brain, but also depends on the capabilities of the body. This basic idea came to be known as embodied cognition. Second, it was shown that cognitive activity also depends routinely on the immediate social and natural environment of the cognitive agent. This came to be known as embedded cognition. Third, it was shown that the boundary of the cognitive agent is not limited to the skin of the cognitive agent. The immediate environment could be a part of the cognitive agent. This was known as extended cognition. These objections and alternative theories introduce contingency into cognition and inherently limit the possibility of cognition being amenable to formal modeling.

Herbert Simon's early optimism about the possibility of formal, rigorous model for design is amply evident in his classic *Sciences of the Artificial.*[21] Contemporaneous work on information processing approaches to design by Christopher Alexander seemed to complement Simon's pioneering work in the 1950s. In the early 1970s, Horst Rittel and Melvin Webber demonstrated the impossibility of a rational approach to design problems by showing that design problems were "wicked" problems – they were problems which could never be completely described.[22] Rittel went on to argue (with echoes of the development in the theory of cognition discussed above) that design is a process in which the theory of knowledge is contingent on the theory of action. A decade later, Donald Schon identified a crisis in the epistemology of technical rationality (this can be understood as the problem-solving approach to producing knowledge) and proposed an alternative approach in which problems would be resolved via a 'reflective conversation with the situation'.[23]

Rittel and Schon represent two critical responses to Simon's instrumental problem-solving approach. The arguments presented by Rittel and Schon have been typically understood as a challenge to possibility of describing a *rational*, systematic process of design. It is proposed that Rittel's most significant contribution was his attention to the question of action rather than the question of knowledge. Schon's objections to instrumental technical rationality, and Rittel's

---

Mind Over Machine (Free Press, 1988). Expertise, according to this theory was the development of intuition, and relied on the primacy of intuition, and not merely faster ways of conducting context-free information processing. Dreyfus's critique was not well received for at least a decade. I discuss this in greater detail in the next chapter. As Allen Newell acknowledged in his 1982 paper Intellectual issues in the history of Artificial Intelligence *"Dreyfus's central intellectual objection, as I understand him, is that the analysis of the Context of human action into discrete 'elements is doomed to failure. This objection is grounded in - phenomenological philosophy. Unfortunately, this appears to be a nonissue as far as AI is concerned. The answers, refutations, and analyses that have been forthcoming to Dreyfus's writings have simply not engaged this issue - which indeed would be a novel issue if it were to come to the fore."* See Allen Newell, "Intellectual Issues in the History of Artificial Intelligence," in The Study of Information: Interdisciplinary Messages, ed. F. Machlup and U Mansfield (New York: Wiley, 1983), 196 – 227.

[20] Howard Gardner, *The Mind's New Science: A History of the Cognitive Revolution* (Basic Books, 1985).

[21] Herbert A. Simon, *The Sciences of the Artificial* (Cambridge, Massachusetts: MIT Press, 1969).

[22] Horst W. J. Rittel and Melvin M. Webber, "Dilemmas in a General Theory of Planning," *Policy Sciences* 4, no. 2 (1973): 155–69.

[23] Donald A. Schon, *The Reflective Practitioner: How Professionals Think in Action* (Basic Books, 1983).

objections (as they are predominantly discussed in the DTM literature) to the possibility of a rational, systematic process of design were objections about the logical claims about the mechanism underlying the design process (as proposed by Simon) – information processing. But Rittel's fundamental idea that any theory of knowledge must be based on a theory of action points to the non-trivial consequences of the affordances, possibilities and limits of action. Simon acknowledges this difficulty in part by accepting that rationality is bounded.[24] But his belief in the computability of thinking led him to underestimate the nature of this boundedness. Responses to Simon's approach can be understood as an effort, in large part, to put action first and the production of knowledge as the consequence of action. But once this inversion was complete, the possibility of a general process or method of design became distant because no general theory of the design action exists. Such a general theory would be useful even if computing was not embedded in designing to the extent that it has been in the last 40 years. But its significance is especially underlined by the emergence of the computer as the ubiquitous machine in design practice.

The early 1970s was a period of optimism about the role of computing in design. Nicholas Negroponte argued that eventually computers would replace architects because building could be designed to be responsive to changing needs.[25] This period also saw the development of early Building Information Modeling (BIM) systems.[26] However, by the mid-1980s, following the theoretical criticisms described above and the technological advances in drafting and the development of tools to enhance productivity, it became clear that computers would best be used as 'design assistants'.[27] Focus shifted to the capacity of computers and computing to extend the designer's capacity to represent and communicate architectural designs, and to represent and evaluate existing and new types of architectural problems. This approach has been largely compatible with the theoretical consensus about design as a practice rather than as a systematic method.

Because of this consensus, scholarship in the field of design has developed along two separate tracks. The first is scholarship about the design process, its structure and the role of representations in this process, and related questions such as creativity and innovation.[28] The second is scholarship in the field of computer aided design which encompasses areas of human-computer-interaction, generative methods and several specialist areas of evaluation such as energy analysis, or acoustic analysis using simulation-based approaches.[29] Sketching has been a significant area of interest due to its capacity as the most common representational mode early in the design process, and due to the possibilities of augmenting or extending the capabilities of the sketch computationally.[30]

---

[24] Herbert A. Simon, "The Logic of Rational Decision," *The British Journal for the Philosophy of Science* 16, no. 63 (1965): 169–86; Herbert A. Simon, "Rationality as Process and as Product of Thought," *The American Economic Review* 68, no. 2 (1978): 1–16.
[25] Nicholas Negroponte, *Soft Architecture Machines* (Cambridge, Mass: The MIT Press, 1975).
[26] Charles M. Eastman, "The Use of Computers Instead of Drawings in Building Design," *AIA Journal* 63, no. 3 (1975): 46–50.
[27] Yehuda E. Kalay, ed., *Computability of Design* (John Wiley & Sons, 1987).
[28] For the most complete recent account about the design process, see Gabriela Goldschmidt, *Linkography: Unfolding the Design Process*, 1 edition (Cambridge, Massachusetts: The MIT Press, 2014). Creativity and Innovation are large fields in their own right and are not within the current scope.
[29] These have contributed to the digital culture described in Picon, *Digital Culture in Architecture*.
[30] A review of efforts to computationally support sketching are discussed in Gabe Johnson et al., "Computational

Augmentation of sketching and architectural representation generally has long been interested in the idea of situating the designer within the representation or making the representation available at “human scale”. Various approaches have involved making mock-ups, offering ‘virtual’ design studios, and developing immersive sketching environments.[31] All these approaches can be understood, in one sense, as efforts to understand how technology mediates the design process. But design has always been a technologically mediated process. A model of a design action should be able to account for new modes of technological mediation as they emerge. A viable model would be unacceptably limited if, say, it worked for virtual studios but not for physical, traditional studios.

Immersive sketching environments are adopted as an example of a technological augmentation of traditional sketching which is has traditionally been an important representational mode of the early architectural design process. These environments aim to allow the designer to “be in the sketch”. In scholarship on human-computer-interaction and virtual reality, immersion has been understood to be a property of the technological medium, while a related concept – presence – is understood to be a property of the user who is using the technological medium.[32] However, these two concepts, as given, do not adequately account for the design situation. A designer is not merely concerned with being present in an immersive representation of a site but is concerned with being able to manipulate the representation and imagine modifications, additions and restructuring of the site. The concepts of immersion and presence do not account for this crucial aspect of a designer’s relationship with the design representation, and thus, a new concept is required. The concept of immersion developed here is an attempt to fill this conceptual gap.

The aim of this thesis, therefore, is to develop a model of design action which accounts for new technological modes. The central importance of the human scale to architectural design grants the idea of immersion a privileged status in the problem of architectural design. However, this immersion is not merely geometrical. It also involves aspects of familiarity and prior knowledge of the site, mobility within the virtual site and ability to manipulate, add and modify features of the site. In this way, immersion emerges as a significant aspect of an architectural design representation medium (or technology). It is proposed that in the context of architectural design, it is appropriate to conceptualize immersion not as a property of the designer, or of the design representation medium, but as a property of the design act. As a property of the design act, immersion also brings forth a third element of the design act, beyond the designer and the representation. This third element is called the *context*.

The viability of this tripartite description of the design act and the role of *immersion* in

Support for Sketching in Design: A Review,” *Foundations and Trends® in Human-Computer Interaction* 2, no. 1 (2007): 1–93.

[31] Christopher Anthony Peri, “Impact of Media on Spatial Communication: From Paper to Collaborative Virtual Environments” (Ph.D. Dissertation, University of California, Berkeley, 2003); Mary Lou Maher, Simeon J. Simoff, and Anna Cicognani, *Understanding Virtual Design Studios*, 2000; Tomas Dorta, “Augmented Sketches and Models: The Hybrid Ideation Space as a Cognitive Artifact for Conceptual Design,” in *Digital Thinking in Architecture, Civil Engineering, Archaeology, Urban Planning and Design: Finding the Ways* (EuropIA.11. 11th International Conference on Design Sciences & Technology, Montreal, Quebec: Europia Publishers, Paris, 2007), 251–64.

[32] M. Lombard and T. Ditton, “At the Heart of It All: The Concept of Presence,” *Journal of Computer-Mediated Communication* 3, no. 2 (1997); Ijsselsteijn and Riva, “Being There: The Experience of Presence in Mediated Environments”; Slater and Wilbur, “A Framework for Immersive Virtual Environments (FIVE).”

this description is examined using a series of exploratory case studies which are described in the final chapter. Advanced graduate students in architecture programs at UC Berkeley and University of Montreal were assigned a conceptual design problem. Some students were asked to design at the site itself. Others were asked to design in an immersive representation of the site using an immersive sketching environment known as the Hybrid Ideation Space (HIS). Still others were given a set of color photographs of the site and asked to work on the same conceptual design problem. After preliminary cases in the three media, further cases were developed involving a similar site which the participants were unfamiliar with. This enabled a comparative examination of work at the site itself, and work in the representation of the site in the immersive sketching environment. This immersive technology is experimental, and these case studies are designed to be exploratory rather than conclusive, but they illustrate that the context and the concept of immersion, are both necessary components of any general account of the design act.

2. Computing in Design: Metaphor

Introduction

In the scholarly tradition of design theories and methods, design is understood to be a purposeful human activity. Several scholarly attempts were made in the 20th century to describe the logical structure of this activity. The computer, which was conceived by Alan Turing and others as a machine to describe other machines, has been guiding metaphor in many of these efforts. At the same time, the digital computer has become an indispensable machine in architectural practice for developing, storing and sharing architectural design proposals. These two parallel histories form the basis of a theoretical account of design as an action.

Attempts to develop a logical structure of designing can be traced back at least to the Bauhaus in Germany in the 1920s. With the theoretical description of the computer by Turing, and the development of the field of cybernetics during World War II, the post-war period saw efforts to develop systematic accounts of designing based on these insights. The current state of the art as far as an understanding of the logical structure of designing is concerned is the result of these attempts and the counter-arguments developed in response to these methods. This period was also marked by contemporaneous development of a computational theory of mind. The progress of this theory informed the progress in the development of design theory.

The core insight about the computer is that it is a machine which can do exactly two things. First, it can perform mathematical calculations. Second, it can remember the results of those calculations. This set of features enables processes to be described as a series of calculations which use, create and update structured information. This enables (for example) the description of processes which occurs in sequence, in parallel, iteratively or recursively. Any information which can be described symbolically can thus be subject to systematic processes and the computer can therefore describe any machine.[33] The problem of building fundamental symbols which behave as the building blocks of architectural designs was foundational to the intellectual development of the Bauhaus.

Bauhaus & Design Theory

The Bauhaus was established in Weimar by the Thuringian state in 1919, initially to revive the crafts. While the school has been the subject of a large body of scholarship due to its influence around the world, the current focus is limited to its core imagination of designing as an activity. Broader aspects of the school such as its re-imagination of the relationship between art and industrial manufacturing are ignored.

The school, led by Walter Gropius among others, developed a radical pedagogy of design and art which had the aim of discarding the "dead wood of convention" and establishing deep skepticism about received knowledge. In place of historical convention, the Bauhaus sought fundamental first principles. Its ambitious approach was epitomized by Johannes Itten's influential "Preliminary Course" (later taught by László Moholy-Nagy and Josef Albers) and complementary courses in Color and Form taught Vassily Kandinsky and Paul Klee. This course

[33] This basic description of a computer can be found in foundational computer programming textbooks. For example, see John V. Guttag, *Introduction to Computation and Programming Using Python*, revised and expanded edition (Cambridge, Mass.: The MIT Press, 2013).

was designed to erase the boundaries between craft and fine art education. Itten's basic pedagogical premise consisted of a radical formalism that all art could be understood in terms of a series of formal oppositions – large/small, long/short, broad/narrow, thick/thin, much/little, straight/curved, pointed/blunt, smooth/rough, hard/soft, transparent/opaque, continuous/intermittent[34] was representative of the larger impulse of the school. The square, the circle and the triangle were considered fundamental formal elements of composition, while the pyramid, the cube and the sphere were considered fundamental spatial elements. These basic forms were first experienced through gesture and motion, after which they were modeled in clay so that they could be felt three dimensionally. It was only after this that they were represented graphically in the compositions to study proportion, pattern, or to study the third dimension on the two-dimensional plane.[35] This experiential emphasis was a part of a larger Bauhaus focus on craft – on making things. The logical-empirical construction of complex forms and spaces from this basic element gave rise to the use of modular elements and grids in the designs of Bauhaus faculty and students. It has been pointed out that these developments took place within a broader culture of standardization in post war Germany. Standardization of fundamental units meant that it was easier to combine.[36]

The Bauhaus emphasis on experience was associated with "contact with material", in the words of Josef Albers, a later teacher of the Preliminary Course.[37] As a design school engaged in integrating art and craft into one unified 'science of art', the emphasis on workshops and making things using various industrial materials and in the process getting to know the materials formed both a practice counterpoint and a complement to intellectual search for fundamental element.

The search for, and application of, fundamental elements based on which formal arrangements could be synthesized and crafted (training in craft was an essential element of the school) carried on from the preliminary course to the larger development of what came to be termed modern architecture itself. The intellectual foundations of this approach were shared and encouraged by the philosophers of the Vienna Circle who were themselves trying to rebuild philosophy from the ground up, based on fundamental propositions and logic. Philosophers like Rudolf Carnap and social scientists like Otto Neurath were often invited to lecture at the Bauhaus, especially in its Dessau years. The Bauhaus and the positivists shared the idea that knowledge was built up from 'neutral bricks'.[38]

The design theory of the Bauhaus was characterized by a rejection of history, the quest for a new beginning based on the search for fundamental elements and the logical assembly of these elements into complicated designed industrial objects that would improve the lives of the people. The school trained its students both to embrace the logical positivist approach to understanding the world, and skills to design and make things using industrial materials. In its foundationalist approach, the Bauhaus anticipated the systematic methods of the post-war era.

---

[34] Johannes Itten, *Design and Form: The Basic Course at the Bauhaus and Later*, Rev. ed (New York: Van Nostrand Reinhold, 1963). 10-11.

[35] Gillian Naylor, *The Bauhaus Reassessed: Sources and Design Theory* (New York: E.P. Dutton, 1985). 78.

[36] Barry Bergdoll and Leah Dickerman, *Bauhaus 1919-1933: Workshops for Modernity* (New York: The Museum of Modern Art, 2009). p. 15-39.

[37] Bergdoll and Dickerman, 32.

[38] Peter Galison, "Aufbau/Bauhaus: Logical Positivism and Architectural Modernism," *Critical Inquiry* 16, no. 4 (1990): 709–52. See especially footnote 82.

The First Conference on Design Theories & Methods and Early Information Processing Approaches

The first Design Methods conference met in London in 1962. The conference was, in the opinion of its organizers, the first to be concerned with the methods, processes and psychology of designing and sought to establish systematic methods of problem solving in design.[39] It was attended by scholars from the fields of engineering, architecture, industrial design and communications. As Peter Slann, an aeronautics engineer wrote in his foreword to the published Conference proceedings, the participants in the conference sought "a means by which design could be taught as a creative process that could be aided by the systematic process of conscious thought, integrating experience with academic knowledge whilst at the same time keeping the imagination free from inhibitions."[40]

J. Christopher Jones proposed a systematic method of design at this conference. This method is also found in Morris Asimov's *Introduction to Design*. This was an iterative method made up of three steps – analysis, synthesis and evaluation (ASE). The analysis stage involved analyzing the situation and producing a problem, the synthesis stage involved synthesizing a solution to the problem developed in the previous stage, and the evaluation stage involved studying the goodness of fit of the proposed solution to the problem in broader situation. This evaluation would lead to further analysis, and so on. This method is a response to an initial proposal at the conference that the task of the designer comprised of three parts – conception, realization and communication.[41]

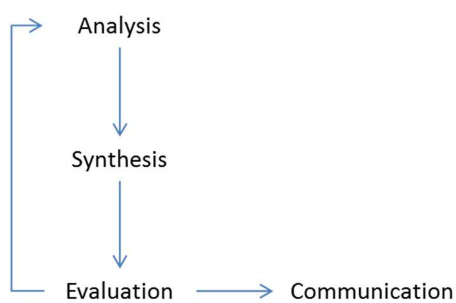


Figure 1 The basic model of systematic design[42]

The early systematic models of the design process emerged from the fields of engineering design, operations research (a discipline that was developed during World War II), management science, and decision theory. These early models involved both the organization of the design process as well as an account of how it proceeds. As model of an activity, this systematic

[39] J. Christopher Jones and D. G. Thornley, eds., *Conference on Design Methods; Papers* (Oxford, New York: Macmillan, 1963).

[40] Jones and Thornley. xi

[41] Morris Asimov, *Introduction to Design*, Prentice-Hall Series in Engineering Design (Englewood Cliffs, N. J.: Prentice-Hall, 1962). Asimov's organization of designing into a series of phases ranging from feasibility to construction has persisted in the field of architectural design and construction. For example, see Charles M Eastman, *Building Product Models: Computer Environments Supporting Design and Construction* (Boca Raton, Fla: CRC Press, 1999).

[42] This basic model has been reproduced widely. This version is based on the one in Kalay, *Architecture's New Media*.

description was abstract and encapsulated expected complexities of design problems. For instance, any realistic design problem would probably involve the resolution of several different sub-problems, each requiring a non-trivial solution. The ASE did not address how solutions to these sub-problems could be defined.

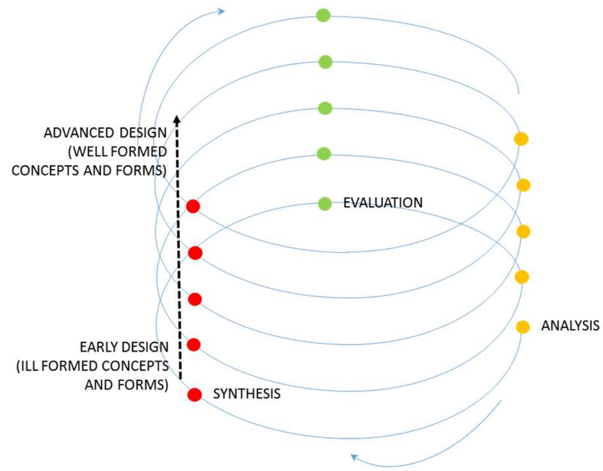


Figure 1: The A-S-E Model in its iterative form was still essentially linear

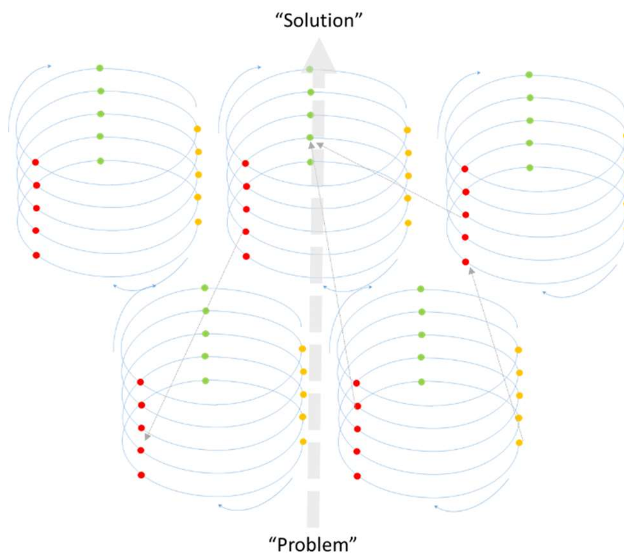


Figure 2: Any reasonably realistic design problem could require many irreducible A-S-E loops which communicate with each other in unforeseeable ways.

Christopher Alexander viewed design as the process of "inventing physical things which display new physical order, organization and form, in response to function", and developed a method of designing which involved breaking down complex design problems into simpler ones which might be more amenable to solution.[43] A method for synthesis of form was needed due to the growing complexity of design problems. Alexander's Ph.D. dissertation, which was later published as *Notes on the Synthesis of Form* included a case study in which he applied the method that he had developed to deal with this increasing complexity of design problems, to

[43] Christopher Alexander, *Notes on the Synthesis of Form* (Harvard University Press, 1964), 1.

“determine the components of an Indian village”. This was presented at the Conference on Design Methods in London.

Alexander saw this complexity in terms of information. “To match the growing complexity of problems” he wrote, “there is a growing body of information and specialist experience. This information is hard to handle; it is widespread, diffuse, unorganized. Moreover, not only is the quantity of information itself by now beyond the reach of single designers, but the various specialists who retail it are narrow and unfamiliar with the form-makers’ peculiar problems, so that it is never clear quite how the designer should best consult them. As a result, although ideally a form should reflect all the known facts relevant to its design, in-fact the average designer scans whatever information he happens on, consults a consultant now and then when faced by extra-special difficulties, and introduces this randomly selected information into forms otherwise dreamt up in the artist’s studio of his mind. The technical difficulties of grasping all the information needed for the construction of such a form are out of hand – and well beyond the fingers of a single individual.”[44] Alexander’s solution was to propose that complex problems could be broken down logically into simpler sub-problems until such time that one got to a level of sub-problem whose solution was simple or trivial.

The reconceptualization of design problems as information processing problems provided a way to deal with greater scales of complexity. Relating sub-problems to the larger problem now became a matter of organizing the information which described the problem in the correct way. In this description of the general structure of design, information became the currency of the design problem.

By the early 1970s, many of the major figures of the design theories and methods approach of the 1960s had developed misgivings. Christopher Alexander, in an interview in the Design Methods Group Newsletter said “I’ve dissociated myself from the field. There is so little in what is called “design methods” that has anything useful to say about how to design buildings that I never even read the literature anymore…. I would say forget it. Forget the whole thing… If you call it “It’s a Good Idea to do”, I like it very much; if you call it “A Method”, I like it but I’m beginning to get turned off; if you call it “A Methodology”, I just don’t want to talk about it.”[45] J. Christopher Jones, who proposed the first unified, systematic model of design and at inaugural Design Methods Conference in 1962, said “In the 1970s I reacted against design methods. I dislike the machine language, the behaviorism, the continual attempt to fix the whole of life into a logical framework.”[46] The problem-solving approach to design, in which solutions were developed by adopting different systematic approaches to complexity of information – sequential and iterative in Jones’s case, divide and conquer in Alexander’s case, seemed to be in decline. The optimism of the early 1960s towards finding a general, systematic process of design that could apply across domains seemed to have collapsed by the 1970s.

Christopher Alexander went on to develop his influential *Pattern Language,* which in a telling phrase, Alexander termed to be constituent of “a timeless way of building”. This approach

---

[44] Ibid., 4. Alexander explicitly casts the problem of complexity as a problem of information processing. See Christopher Alexander, “Information and an Organized Process of Design,” *Proceedings of the Building Research Institute*, no. Spring 1961 (1961): 115–24.

[45] Christopher Alexander, “The State of the Art in Design Methods,” *DMG Newsletter* 5, no. 3 (1971): 3–7.

[46]J. Christopher Jones, “How My Thoughts about Design Methods Have Changed during the Years,” *Design Methods and Theories* 11, no. 1 (1977): 48–62.

was more influential in the field of computer programming, where it helped develop the paradigm of object-oriented programming, than in the field of architectural design, for which it was developed. A pattern, as defined by Alexander, was a problem along with a solution to it. Instead of breaking down a complex problem into its simplest sub-problems, patterns offered a basic kit of parts or as a computer scientist would call it, components of a generative grammar for developing design solutions. In their pattern language for Towns, Buildings and Construction, for example, Alexander and his colleagues provide patterns that are as expansive as "a town for 7000" to the design of a doorknob. The premise behind the pattern language is that every new design situation, while probably unique, can still be addressed through a combination of prototypical patterns.[47]

If design problems cannot be broken down into fundamental, simple parts (which by themselves are trivial problems), then can they be broken down into ideal parts (Alexander's patterns)? Conversely, if fundamental parts, be they the simplest, most "fundamental" elements, or the most "appropriate" parts, cannot be defined reasonably, can designing then be explained through an arithmetic of transactions at all? Even if a system of iterative steps – analysis, synthesis and evaluation – could be said to constitute a systematic method of design, there is no reason to expect that this would lead to good design unless the problem of complexity was resolved. A description of a design 'method' did not yet exist. Alexander first posited that the design problem could be repeatedly decomposed into simpler sub-problems until the sub-problems at hand were trivial. In the pattern language, he proposed essentially the opposite view – that instead of trivial, self-evident building blocks, design problems in architecture had to be solved by combining fundamental "timeless" patterns which were non-trivial.

Whether or not these were good patterns, whether there was a good way of judging these patterns, or whether it was even possible to say that what an objectively good pattern ought to be, has remained a matter of debate. This issue is revisited in the next section following a discussion of Herbert Simon's approach to design.[48]

Simon: Science of Design

Herbert Simon was among the most celebrated scientists of the second half of the twentieth century. A political scientist by training, he is the only person to be awarded the highest prize in computer science and economics.[49] In the late 1960s, Simon sought to develop a

---

[47] Christopher Alexander, *A Pattern Language: Towns, Buildings, Construction* (New York: Oxford University Press, 1977).

[48] Jean-Pierre Protzen wrote a review of Alexander's Pattern Language in 1977 entitled 'The Poverty of the Pattern Language' in which he argued that the patterns in the Pattern Language themselves were subjective – that it was unclear that they were objectively good. Protzen's review of the book and Alexander's reply was reproduced in the first volume of the refereed scholarly journal Design Studies. See Jean-Pierre Protzen and Christopher A. Alexander, "Value in Design: A Dialogue," *Design Studies* 1, no. 5 (July 1980): 291–98.

[49] Herbert Simon was awarded the Nobel Memorial Prize in Economics in 1978 for his "for his pioneering research into the decision-making process within economic organizations", and the Association for Computing Machinery's Turing Award in 1975 for "basic contributions to artificial intelligence, the psychology of human cognition, and list processing". At Carnegie Mellon University, he was affiliated with Computer Science, Psychology, the Business School, Philosophy, and the Social and Decisions Sciences. In an intellectual history of Simon's life and work, the historian Hunter Crowther-Heyck characterized the ambition of Simon's work as being "to bring the complex and chaotic world of human thought and action within the ambit of rational, empirical science" by bringing together the 'sciences of choice' – game theory, utility theory, and statistical decision theory, and the 'sciences of control' –

unified 'science of the artificial', which he called design. He defined design as a course of action aimed at changing existing situations into preferred ones.[50] Determining this course of action would be "a body of intellectually tough, analytic, partly formalizable, partly empirical, teachable doctrine about the design process."[51] Simon had earlier argued that people (consequently, designers) are "intendedly rational", but that their rationality is limited because of practical limits in the amount of information they have, by their ability to process this information, and in the amount of time that they have to process it.[52] Even though Simon identified this technical limit to rationality, he only saw it as a problem when one was seeking optimal solutions, not satisfactory ones. Satisfactory solutions ('satisficing' according to Simon), were solutions which were sufficiently good without a claim to the effect that they were the best possible solutions.

The computer was the central tool for developing this science of design. In the third edition (1996) of *Sciences of the Artificial* Simon observed that the science of design had been emerging since the 1970s and that his book, first published in 1969 had been influential in its development. Simon's design theory was aimed at broadening the capacity of computers to aid design, drawing on tools of artificial intelligence and operations research. By 1961, Newell and Simon were already able to claim that "It is no longer necessary to argue that computers can be used to simulate human thinking, or to explain in general terms how such simulation can be carried out…. Computer programs now play chess and checkers, find proofs for theorems in geometry and logic, compose music, balance assembly lines, design electric motors and generators, memorize nonsense syllables, form concepts, and learn to read."[53] With Allen Newell and J C Shaw, Simon had early proposed a theory of human problem solving in which they postulated that problem solving consists of processes that can be "compounded out of elementary information processes". They explicitly drew an analogy with the digital computer asserting that "the appropriate way to describe a piece of problem-solving behavior was in terms of a program: a specification of what the organism will do under varying environmental circumstances in terms of certain elementary information processes it is capable of performing."[54] This understanding of problem solving influenced Simon's work in the new field of cognitive science, but it also shaped his understanding of design as a problem solving activity.

Simon saw design as a problem of optimization. The artifact (the thing being designed) is the "meeting point" between an "inner environment" (the substance and organization of the artifact itself) and an "outer environment" (the surroundings in which the artifact operates). The core problem of the design was to adapt the artifact to its environment. Simon saw rationality playing the same role in design (the science of the artificial) that natural selection did in evolutionary biology. Computational methods were not only applicable for problems of

---

behaviorist experiment psychology, anthropology, sociology, social psychology and political science. See Hunter Crowther-Heyck, *Herbert A. Simon: The Bounds of Reason in Modern America* (JHU Press, 2005), 5.

[50]Simon, *The Sciences of the Artificial*, 111.. The first edition was published in 1969. It was based on Simon's Karl Taylor Crompton Lectures at MIT in 1968.

[51] Simon, 113.

[52] Herbert A. Simon, *Models of Man: Social and Rational; Mathematical Essays on Rational Human Behavior in Society Setting* (New York: Wiley, 1957).

[53]Newell and Simon, "Computer Simulation of Human Thinking and Problem Solving," 4.

[54]Allen Newell, J. C. Shaw, and Herbert A. Simon, "Elements of a Theory of Human Problem Solving.," *Psychological Review. Vol 65(3)*, 1958, 151–66..

optimization, they could also produce sub-optimal, or merely satisfactory solutions. To use Simon's term, "satisficing" solutions could also be achieved through computation. Design would proceed through an iterative process of proposing solutions and then evaluating how well these solutions (or these descriptions of the 'inner environment', each description being in terms of a set of variables) fit or were adapted to the outer environment. Like the early Alexander, Simon proposed that complex environments (or systems)[55] could be described hierarchically by considering them to be constructed with a hierarchy of levels – they can consist of subsystems, which in turn can be comprised of their own sub-systems. Each of these subsystems has its own inner environment governed which can be defined without worrying about the inner environments of its sub-systems.

Underpinning this information processing apparatus in which design could be conducted rigorously as an optimization or satisficing problem was the proposition that problems could be defined well, if not by themselves, then as combinations of other well-defined problems. The problems accessible to a problem solver had to be well-structured. In *The Structure of Ill-Structured Problems* Simon tried to show that a class of problems defined as "ill-structured" (ISPs) were not inaccessible to the problem-solving systems of artificial intelligence (AI) (like the General Problem Solver (GPS)).[56] The class of problems defined as "well-structured" (WSP) was accessible to the problem-solving systems of AI. Simon observed that "In general, the problems presented to problem solvers by the world are best regarded as ISPs. They become WSPs only in the process of being prepared for the problem solvers. It is not exaggerating much to say that there are no WSPs. only ISPs that have been formalized for problem solvers."[57] Simon used the examples of Chess playing and theorem proving and showing that for all practical purposes, each of these is not a strictly a WSP. Simon proposed that a WSP "contains a countable set of symbols (S), finite sequences of which are called expressions; a subset F of the expressions are called well-formed-formulas (wffs) of S, and a set of the F's are called axioms. There is a finite set R of relations among F's called rules of inference. If there are j wffs that stand in the relation Rj to a wff C, where Rj is one of the rules of inference, then C is a direct consequence of these j wffs. A proof in S is a sequence of wffs, each of whose members is either an axiom of S or a direct consequence of some of the preceding wffs by the rules of inference. A theorem T of S is a wff such that there is a proof in S whose final member is T."[58] A WSP then, is one which can be solved by the GPS.

Having argued that WSPs exist only ideally and not in actual practice even in the case of chess playing or theorem proving due to the existence of practical limits, Simon turned his attention to ISPs. His chosen example was that of designing a house. The problem of designing a house fails many of the tests of the WSP. No criterion for testing solutions is readily available, let alone mechanizable. The scope of the problem and the problem space are difficult to define. However, in the process used by architects to solve the problem of designing a house, Simon saw, like Alexander did in his *Notes in the Synthesis of Form*, a systematic effort to decompose problems into smaller, more manageable sub-problems. Simon concluded "The whole design,

[55] Simon uses the word 'system' and 'environment' interchangeably at times in Chapter 5 of The Sciences of the Artificial.

56 Herbert A. Simon, "The Structure of Ill Structured Problems," Artificial Intelligence 4, no. 3–4 (1973): 181–201; Newell, Shaw, and Simon, "Elements of a Theory of Human Problem Solving."

[57] Simon, "The Structure of Ill Structured Problems," 186.

[58]Herbert A. Simon, "Bradie on Polanyi on the Meno Paradox," *Philosophy of Science* 43, no. 1 (1976): 148.

then, begins to acquire structure by being decomposed into various problems of component design, and by evoking, as the design progresses, all kinds of requirements to be applied in testing the design of its components. During any given short period of time, the architect will find himself working on a problem which, perhaps beginning in an ill structured state, soon converts itself through evocation from memory into a well-structured problem. We can make here the same comment we made about playing chess: the problem is well structured in the small, bat ill structured in the large."[59]

Simon's idea of the ill-structured problem is perhaps best understood in the context of his position on the boundedness of rationality. The GPS could provide a solution to the problem of designing a house, provided that the main problem was properly broken down into sub-problems. Further, since this solution to the problem would be rational and satisficing, Simon contended that it would be a satisfactory solution to the problem. Thus, Simon proposed a way to systematic produce satisfactory solutions to ill-structured problems. Simon's account of design was part of a larger argument he made about the nature of the mind and of its relation to the body. The mind bore the same relation to the body that a computer program bore to the physical computer. This is explored in greater detail in the next chapter. For now, it is sufficient conclude by pointing to two issues which arise in Herbert Simon's advanced account of systematic, rational design. First, there are the related issues of rationality and problem description. Second, there is the issue of embodiment. Next, the Function-Behaviour-Structure model proposed by John Gero is discussed.

Gero's Function-Behavior-Structure Approach

John Gero developed the influential Function-Behavior-Structure (FBS) knowledge model as a representation framework for studying and explaining design.[60] The knowledge model is a system which accommodates the systematic iterative design loop consisting of analysis, synthesis and evaluation phases proposed by Jones and others in the 1960s.[61]

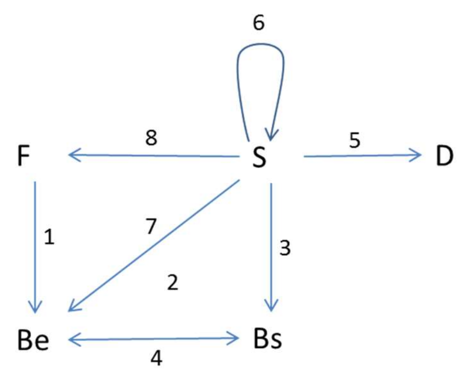


Figure 2 The Function - Behavior Structure knowledge model for Design[62]

---

[59] Simon, "The Structure of Ill Structured Problems," 190.

[60] This account relies primarily on two publications which Gero has subsequently cited as core statements of his approach and model. See John S. Gero, "Design Prototypes: A Knowledge Representation Schema for Design," *AI Magazine* 11, no. 4 (December 15, 1990): 26; John S. Gero and Udo Kannengiesser, "The Situated Function–Behaviour–Structure Framework," *Design Studies* 25, no. 4 (July 2004): 373–91.

[61] Jones and Thornley, *Conference on Design Methods; Papers*.

[62]Gero and Kannengiesser, "The Situated Function–Behaviour–Structure Framework," 375.

This approach involves a model of the design object, i.e. the object to be designed, in terms of its function, structure and behaviour. Designing is act of achieving these goals. This abstract definition of the design object allows Gero to specify the types of design steps which are possible and therefore, to systematically enumerate the types of design steps which occur (since all the design steps which occur are of one of the specified types). The combined model of design is shown in the figure below.

In the figure above, F – Function, Be – Expected Behavior, Bs – Behavior derived from structure, S – Structure, D – design description. Arrows in a single direction indicate a transformation, while bi-directional arrows indicate a comparison. The numbers indicate the sequence of steps in the iteration. The steps are as follows. The enumeration represents corresponding numbers in the figure above:

One: Formulation: The Function (F) contains descriptions of the design requirements. These are transformed into the behavior (Be) that is expected to meet these requirements.

Two: Synthesis: Here the expected behavior (Be) is transformed into a solution structure (S). The idea is that S will exhibit Be.

Three: Analysis: Here the actual behavior (Bs) of the proposed solution structure (S) is determined.

Four: Evaluation: The actual behavior (Bs) is compared to the expected behavior to determine if the proposed design solution (S) is acceptable.

Five: Documentation: Here a design description is produced for manufacturing (S) if (S) is acceptable.

Steps Six, Seven and Eight describe three distinct types of reformulation.

Six: Reformulation Type 1: In this, if the actual behavior of the proposed design solution is found to be unsatisfactory, the solution is appropriately modified in terms of structure variables, or values for these variables.

Seven: Reformulation Type 2: In this, if the actual behavior of the proposed design solution is found to be unsatisfactory, the solution is appropriately modified in terms of behavior variables or their values.

Eight: Reformulation Type 3: In this, if the actual behavior of the proposed design solution is found to be unsatisfactory, the solution is appropriately modified in terms of the function variables or their values.

Gero and Kannengiesser later extended this model to account for 'situatedness' and 'constructive memory', to provide a systematic model for conceptual design. The authors argued that conceptual designing had the distinguishing feature that "not all the requirements are known at the outset of a design task" and it involved "finding what is needed and modifying it again during the process". The authors aim was to develop "a model of designing in which all the world is not encoded a priori, and which allows for a changing world within which the agent operates."[63] These are related ideas. Situatedness, for the authors, is the result of the empirically observed fact that the interaction between the designer and the environment "strongly determines" the course of designing, and consequently, the result of the activity. 'Constructive

[63] Gero and Kannengiesser, 373.

memory' is a Deweyian concept which entails that memory is not merely recalled but constructed with a combination of recollection of the original experience and the demands of the situation at the time when the memory is demanded. Revisiting the information processing metaphor, while the first idea – situatedness, suggests that the exchange of information by itself does not explain designing, the second idea – constructive memory, suggests that recollection of stored information by itself does not explain even the way in which precedent may be available in any given moment, let alone how it may be applied.

Gero and Kannengiesser provide models of situatedness and constructive memory to create "a dynamic context for designing". Situatedness is modeled as an interaction between three worlds – an external world (external representations), an interpreted world (internal representations developed from percepts, concepts and sensory experiences) and an expected world (a world which the designer's actions will predictably produce). The expected world is located within the interpreted world (i.e. it is also an internal representation).[64] They model constructive memory in a similar way, defining it to be the result of a "push and pull" process between worlds.

Gero's approach extends Simon's work by providing a more detailed account of how the Simon's inner and outer environments can be evaluated and updated. By separating function (the purpose to be served), the behavior (the way in which this purpose will be served) and the structure (the figurative machinery required to produce the required behavior), this systematic account of designing enables the information in Simon's model to be organized in greater detail.

So far, attempts to describe design as a systematic process amenable to symbolic information processing in some form have been discussed. These approaches invited significant criticism. These are discussed in the next chapter.

Summary

In this chapter, four efforts to model design as a systematic process involving some form of symbolic information processing have been discussed. Each of these approaches could be considered "first generation" approaches. These approaches varying in the extent to which they elaborate the conceptual structures involved in information processing. Gero's approach, which is the most advanced (and recent) approach of this type, specifies a conceptual structure which enables the description of a generalized design object and the relationships and transformations involved in bringing it about. Alexander's approach to the synthesis of form specifies that design problems should be repeatedly decomposed into sub-problems until elementary problems (whose solutions are trivial) are reached, at which point, the solutions should be recombined. Simon proposes the most generalized information processing approach consisting of different types of memory and enabling the definition of differently organized (or structured) information.

Each of these approaches try to define an abstract, general design process from the ground up. In this, belong in the modern tradition of the Bauhaus. These approaches also adopt the information processing logic of the modern computer. In the next chapter, several criticisms

[64] "Internal" and "External" representations become necessary because Gero is committed to developing computational frameworks for designing, and assumes (or must necessary assume) that situations and memories are also inherently computable, just as designing must be an inherently computable process. The FBS framework and its extension are models of a computer program as much as they are proposed as models of designing. See footnote 14 on page 378 of Gero and Kannengiesser, "The Situated Function–behaviour–structure Framework.",

to these approaches and their consequences are discussed.

3. Computing in Design: Limitations and Counterpoints

Introduction

The ambition to describe design systematically led to the development of computationally based descriptions of the design process as a systematic, iterative, information or knowledge processing activity. Four attempts which used these approaches were discussed in the previous chapter. These attempts span the period from the 1960s to the late 1980s. These attempts to formalize and demystify designing were at odds with the prevalent practice in the architectural design profession and pedagogy. The dominant paradigm of design education was the architectural design studio. The premise of the studio education was that students would learn about design by practicing it in a controlled studio environment. As they advanced in their education, students would be confronted with increasingly complex design problems and be asked to propose increasingly sophisticated design proposals. In most cases, this sequence of studio courses would be accompanied by a series of required and optional subject courses in architectural history, computer software, building bye-laws and other fields. In many cases, this sequence of coursework would culminate in a thesis project where the student developed first, a problem, and then a solution to this problem.[65]

This separation between attempts to develop systematic design methods and persistence of practice in the professional architectural design studio was symptomatic of, and contributed to, multiple critiques of these attempts. In part, these critiques mirrored the broader critiques of the limits of the positivist scientific method. The idea of a general method for design which developed out of Norbert Wiener's cybernetics harked back to the Vienna Circle of the 1930s and its effort to create a unity of science.[66] Herbert Simon's attempt to conceptualize design as the science of the artificial (as discussed in the previous chapter) can be understood in this context.[67] The systematic method posited that design was a purposeful activity whose aim was to convert an existing situation into a desired situation through a systematic, iterative process in which both situations (and indeed, any situations) were modeled informationally and could be updated and evaluated using information processing methods.

Critiques of these attempts and the methods they produced can be understood to be of two types. The first criticism can be considered the 'rationality critique'. This critique challenged the idea that design problems were amenable to rational solutions, and that purely rational approaches to developing solutions were viable or even possible given the nature of design problems. The second criticism can be considered the 'action critique'. The essential point of this criticism was that symbolic information processing did not adequately account for the

---

[65] See Donald A Schön, *The Design Studio: An Exploration of Its Traditions and Potentials*, Architecture & the Higher Learning (London: RIBA Publications Ltd., 1985). For a view from the profession see Edward Robbins, *Why Architects Draw* (Cambridge, Mass: MIT Press, 1994). Robins argues that the drawing serves the basis for an architect's social standing. The practice of architecture depends on the architect's unique ability to produce drawings.

[66] For an extended discussion of the concept of a 'unity of science' and the development of cybernetics during the second world war see Peter Galison, "The Ontology of the Enemy: Norbert Wiener and the Cybernetic Vision," *Critical Inquiry* 21, no. 1 (1994): 228–66. Galison also explores questions about the disunity of science, and the limits to these attempted unities in Peter Galison and David J. Stump, eds., *The Disunity of Science: Boundaries, Contexts, and Power*, 1 edition (Stanford, Calif: Stanford University Press, 1996).

[67] Simon, *The Sciences of the Artificial*.

complexity and contingencies involved in design actions. Some of these critiques are direct responses to the work of Herbert Simon and his colleagues in the field of design methods. Other critiques, discussed in the second part of this chapter, are based on broader critiques of the model of cognition on which the approach of Simon and his colleagues is based. Hubert Dreyfus's critique of the information processing approach to cognition is illustrated through a discussion of his account of expertise. Dreyfus's argument can be understood to state that expertise involves a restructuring of processes because it involves a transformation of the participant, and therefore of her disposition to the process. The thesis of this chapter is that this broad set of direct and indirect critiques broadly organize themselves into the rationality critique and the action critique, and that it is the latter which is especially constructive.

Rittel: Wicked Problems and Reasoning Designers

An early voice of dissent or perhaps caution at the inaugural conference on design methods in 1962 was Joseph Esherick, a professor of architecture at the University of California, Berkeley. In a paper titled *Problems of the Design of a Design System*, Esherick argued that while it was beguiling to think the design problems were fundamentally like problems in the physical science (i.e. they were amenable to systematic solutions), design was a social science problem characterized by its very ambiguity, by its "wooliness, its vagueness, its unwillingness to be pinned down", and that any system of design must preserve this capacity for ambiguity.[68]

By the end of the 1960s, Horst Rittel presented a critique of the problem-solving approach which relied on a specific understanding of the peculiar nature of design and planning problems. The information processing based problem solving method assumed that problems could be defined separately from solutions. Furthermore, it was assumed and expected that problems could be defined well enough to be solved. Rittel argued that to define a problem was also to define (limit) ways to solve it. The way a problem was defined limited and focused the nature of the solution that would then be developed for it.[69]

While Herbert Simon deployed the concept of a bounded rationality to account for the limits of a rational individual's capacity to make sense of the world, Horst Rittel saw a paradox in that idea of rationality, which made rationality a problematic hinge on which to systematize designing. Rittel defined rational behavior as "trying to anticipate the consequences of contemplated actions."[70] In his 1972 paper, Rittel explains the problem of trying to behave rationally through a fourfold paradox. This is discussed in terms of Rittel's response to the information processing approach, since Rittel's criticism of rational design methods were a response to the problems he found in "first generation" approaches to design theory.

The first paradox of rationality is that it is impossible to start to be strictly rational, for if being rational involves tracing the consequences of one's actions, then before one begins to trace the consequences of one's actions, one must trace the consequences of the tracing the consequences of one's actions. There are consequences all the way down.

The second paradox of rationality is that even if we assume that it is possible, somehow, to start being strictly rational, once you start, it is impossible to rationally stop. Even if one can begin to examine the consequences, since consequences themselves have consequences (there is

[68] Jones and Thornley, *Conference on Design Methods; Papers*, 76.

[69] Rittel, "On the Planning Crisis."

[70] Rittel, 391.

no reason to assume that they don't), there is no way to stop examining consequences from within the logic of the problem.

The third paradox of rationality is that even if one succeeds in being rational, the more successful one is at being rational, the more incapacitated one is. This is because as one develops causal chains of consequences deeper into futures, the less one can say which of these terminals will eventually become the case because of a specific course of action. A consequence of this is that the more one succeeds in being rational, the less one can derive from this about what one should do.

Rittel's fourth paradox of rationality deals with the question of self-containment. To study the consequences of contemplated actions, one needs a model. A model here is defined by Rittel as "a causal description of the phenomena which are affected by the contemplated actions or affect the actions."[71] This model should be able to account for and describe all the factors which are important. This inevitably means that the model should be able to account for itself, and hence, contain itself. This is impossible.

Even though Rittel does not explicitly cite Simon's concept of bounded rationality in his paper, his critique of rationality can be seen to be question the idea that bounded rationality (which itself was developed as a criticism of the dominant assumption of optimal rationality in economics at the time) can be considered sufficient for the judgment required in designing or planning. Rittel explicitly contrasts planning problems from "the problems of the scientist, the engineer or the chess player."[72] Rittel then proposes a classification between "wicked" and "tame" problems. I will not provide an exhaustive list here but will limit myself to the relevant aspects of this classification.[73]

The first and most important property of a wicked problem is that it defies exhaustive formulation. As Rittel puts it "The first property is that a tame problem can be exhaustively formulated so that It can be written down on a piece of paper which can be handed to a knowledgeable man who will eventually solve the problem without needing any additional information."[74] All the information necessary for solving the problem is available in the formulation of the problem itself, if the problem is given to a knowledgeable man. The second property is that "The second property in contrast to tame problems is that *every formulation of the WP corresponds to* a *statement of the solution* and vice versa."[75] A "wicked" problem flouts nearly all the requirements of a well-structured problem, or the properties of a problem fit for a General Problem Solver as formulated by Herbert Simon. Wicked problems have no stopping rule, their solutions cannot be evaluated to be either true or false, but only good or bad, there is no exhaustive list of permissive operations which can be performed in the case of a wicked problem, every wicked problem can be considered a symptom of another problem, wicked

[71] Rittel, 392.

[72] Rittel, "On the Planning Crisis." This reference to chess is important, as playing chess was considered one of the key problems in artificial intelligence. For Allen Newell and Herbert Simon, the possibility of writing a computer program that could play chess – a difficult but well-defined problem, was important proof of the idea that thinking is computational. Chess is a well-defined problem because at any given time, all possible legal moves are known as are the conditions for ending the game.

[73] For an exhaustive list, see Rittel and Webber, "Dilemmas in a General Theory of Planning."

[74] Rittel, "On the Planning Crisis," 392.

[75] Rittel, 392. Emphasis in the original

problems have no natural form or a clearly available level of analysis.

It is the first two properties of the wicked problem which are essential to my argument here. Simon's argument that ill-structured problems are basically assemblies of well-structured problems which appear to be ill-structured and are therefore amenable to being addressed successfully by computational artificial intelligence treats the availability of information as an externality. The problem is informational, and thus, requiring more information is an issue which can simply be tackled by designing an appropriate information processing system – one which can access a long-term memory and if necessary, the external world. For Rittel, the informational nature of what he terms the "tame" problem is precisely what separates it from wicked problems. This insight led Rittel to argue that design can only proceed through a process of argumentation, and that designers have "epistemic freedom."[76]

The designer's epistemic freedom stems from the fact that in the process of argumentation through which designing must proceed, there are "no logical or epistemological constraints or rules which would prescribe which of the various meaningful steps to take next. There are no 'algorithms' to guide the process. It is left up to the designer's judgment how to proceed. There is no – logical or other – necessity to want or to do something particular in response to an issue".[77] An "issue" for Rittel formed the basis of a problem-solving system for design, planning or policy related problems.[78] He developed the Issue Based Information System (IBIS) for this purpose.[79] The design and implementation of the IBIS is an illustration of the type of computational support for design which would result from a view of designing like Rittel's. [80]

The "Issue" is the organizational "atom" of IBIS. It takes the form of a question and originates in controversies. It is specific to a situation, and positions on an issue are developed by utilizing information from the problem environment, and from other cases claimed to be similar. An issue can be "argued, settled, "dodged" or substituted".[81] Four types of information exchange about issues' occur in IBIS. Information can be exchanged between participants in the argument, it can be exchanged with experts about specific questions, it can be gleaned from documentation systems, and it can be exchanged with a client of decision maker, if such an entity is part of the argument. IBIS was implemented in both manual and electronic (computer based) forms. A UNIX based implementation was completed by Noble and Rittel in the late 1980s.[82]

Rittel's conception of designing or planning as argumentation had the virtue of making the working procedures of design transparent. The concept of the "issue" and the explicit

---

[76] Horst W. J Rittel, "The Reasoning of Designers" (International Congress on Planning and Design Theory, Boston, MA, 1987).

[77] Rittel, 5.

[78] Werner Kunz and Horst W. J Rittel, *Issues as Elements of Information Systems*, Working Paper - Center for Planning and Development Research, University of California, no. 131 (Berkeley: Institute of Urban and Regional Development, University of California, 1970).

[79] Douglas Noble and Horst W. J Rittel, "Issue-Based Information Systems for Design," Working Paper, Institute for Urban & Regional Development (Berkeley, California: University of California, Berkeley, 1989).

[80] Rittel's concept of "epistemic freedom" with its emphasis on "judgment" which is not algorithmic in nature echoes Hubert Dreyfus's notion of intuitive expertise (this is discussed towards the end of this chapter). However, the level of analysis is different – Rittel's concern was with design as a social-technical activity in the world, Dreyfus's concern was with an individual's coping in the world.

[81] Kunz and Rittel, *Issues as Elements of Information Systems*, 4.

[82] Noble and Rittel, "Issue-Based Information Systems for Design."

distinction of modes of information exchange reveal that information, for Rittel was uneven, and did not exist meaningfully, absent a problem, or an argument. Information is discourse dependent, it is not flat. This effort to make visible the uneven nature of information, or of the content of the discourse that makes up the activity of designing or planning, is further reinforced by Noble and Rittel's classification of the types of knowledge that is involved in the resolution of Issues. They offer 5 types of knowledge – Factual (Is X the case?), Deontic (Should X be the case?), Explanatory (What causes X?), Instrumental (How can X be brought about?) and Conceptual (What do you mean by X?). [83] The function of the Information System is to record and organize how the argument proceeds. It serves as a structured repository for the design.

This relatively modest use of the computer's capacity to process information in the design or planning processes is emblematic of the limitations of the computer metaphor in understanding design. While Rittel viewed information as an outcome of designing and designing itself to be dealing largely with 'wicked' problems (beyond the scope of positive rationality), others in this period attempted to develop knowledge models which would be sophisticated enough to allow designing to be studied using them.

Rittel's central insight was that design problems were unique because they could never be completely described. Hence, a rational method to solve problems was impossible. In his approach, Herbert Simon accepted that design problems were ill-structured and ill-defined, and that designers were boundedly rational beings, but Simon nevertheless persisted with the view that symbolic information processing could adequately model the development of the design solution. By introducing the concept of the issue as the currency of designing as an activity, and granting designers 'epistemic freedom', Rittel introduced the idea that information (or knowledge, to use Gero's term) involved in designing could be uneven and mutually irreducible, and that processing it would regularly require designers to exercise judgement. The implication of Rittel's view is that the system used to store, and update issues plays a significant role in method of design.

In the conclusion to his seminar of design, Rittel invoked Kenneth Boulding's concept of the Image to point out the significance of a theory of action to any theory of design.[84] This significance of the theory of action is a direct result of Rittel's insight that information processing in design involves storing and updating often mutually irreducible issues using limited means. Rittel writes "Any theory of innovation including a theory of design must be based on a theory of action, not on a theory of knowledge (epistemology) alone. Such a theory of action should contain a theory of knowledge." Rittel continues: "Such a theory has to consider the connection between perception and action in the complicated way following from the fact that what we perceive depends on what we expect to perceive, and what we expect to perceive depends on what we have experienced."[85]

[83] Noble and Rittel, 4.

[84] Boulding argued that organisms do not react to reality directly, but receive selective messages from the environment. Humans have the capacity to transmit and receive messages in symbolic form (language) and to save these messages using marks. A human beings understanding of reality is an 'image' which is the result of a complex of such messages. Boulding went on to argue that when people act in reality, they use some subset of this 'image', and went on to propose a new area of study which he called 'Eiconics' as the study the economy of these messages. See Kenneth Ewart Boulding, *The Image: Knowledge in Life and Society* (Ann Arbor: University of Michigan Press, 1956).

[85]Protzen and Harris, *The Universe of Design*, 144.

Schon: Reflection-in-action

Donald Schon diagnosed a crisis of confidence in professional knowledge (knowledge which professions laid claim to as the basis of their existence). [86] Writing in the early 1980s, Schon observed that "when leading professionals write or speak about their own crisis of confidence, they tend to focus on the mismatch of traditional patterns of practice and knowledge to features of the practice situation – complexity, uncertainty, instability, uniqueness, and value conflict – of whose importance they are becoming increasingly aware."[87] This professional unease, for Schon, was a symptom of the prevailing dominant epistemology of practice, which he called "Technical Rationality". According to this model of practice, "professional activity consists in instrumental problem solving made possible by the application of scientific theory and technique."[88] The systematic knowledge base of a profession (which makes professional activity possible) has four essential features – it is specialized, firmly bounded, scientific, and standardized. Professional problem solving takes place through the systematic application of this specialized knowledge to real world problems. In Schon's account, this confidence in instrumental problem solving was eventually, and especially in the period from the 1960s to the early 1980s, disturbed by the realization that to have a problem that could be solved, a problem had to first be established. Setting up a problem was not in itself a technical problem. This became an increasingly widespread realization in professional practice.[89] Schon's model of reflective practice is at its core a response to this shortcoming of the epistemology of "Technical Rationality".

Despite his criticism of technical rationality, Schon was nevertheless interested in identifying a fundamental process in design. He chose to study architecture because he considered it the oldest of the design professions and functioned as a "prototype for design in other professions". If there was one profession in which a fundamental process of design would be evident, it would be in architecture.[90] The process Schon identified involved a dialogue between the designer and the situation of the design. In Schon's famous phrase, good designing consisted of a designer having a "reflective conversation with the situation" in which the situation "talked back" and the designer "reflected-in-action".[91] As a result, designing progressed through a continuous reframing of the problem. Since the design problem in every case is nearly unique in the case of architectural design and often not fully defined, the major difficulty lies in identifying the problem.[92] The only way in which the design can proceed is through a constant

---

[86] Schon, *The Reflective Practitioner: How Professionals Think in Action*.

[87] Schon, 18.

[88] Schon, 21.

[89] Examples of professional practice for Schon, defined along the lines of the epistemology of technical rationality, are medicine, law, engineering, architecture and psychotherapy among others. As Schon writes – "Technical Rationality depends on an agreement about ends. When ends are fixed and clear, then the decision to act can present itself as an instrumental problem. But when ends are confused and conflicting, there is as yet no "problem" to solve. A conflict of ends cannot be resolved by the use of techniques derived from applied research. It is rather through the non-technical process of framing the problematic situation that we may organize and clarify both the ends to be achieved and the possible means of achieving them" Schon, 41.

[90] Schon, 77.

[91] Schon, 81.

[92] This is not an uncontested idea. Many architectural firms, for example Project Frog in San Francisco, base their approach to architectural design on the idea that architectural design problems are not unique. The claim about

reframing of the problem. Reflection-in-action, Schon proposed is the actual epistemology of practice in design. Schon described 3 core aspects of this proposed epistemology.

First, given that reflection-in-action involves reframing the problem setting, there must be a way to evaluate how well the problem has been reframed. This is done in at least two ways. It depends on the ability of the designer to solve the reframed problem. It is also done by considering the being aware of and alive to the unintended consequences of such reframing. The process by which this is evaluated is described by Schon as an "exploratory experiment" (and later as a "move experiment."[93] This is distinct from the conventional scientific experiment which involves testing hypotheses, because in this case, the designer (or the experimenter) is in the situation that is being tested. So, any change to the situation that occurs as part of the experiment, changes the designer (experimenter) as well. The designer engagement with the situation is for two purposes – to understand the situation, and to change it. The situation is changed by making a move in it. This type of exploratory experimentation is rigorous when the designer strives the make the situation confirm to her view of it, while at the same time remaining open to the evidence of her failure to do so. In the event of failure, the designer must remain open to the possibility that this is due to a problem with the hypothesis as well as the possibility that this may be because the problem has not been framed properly. The experiment in practice proceeds according to a logic of affirmation and not confirmation.[94]

Second, the problem of bringing prior knowledge to bear on a situation which is understood to be unique, is resolved by Schon with the argument that every new situation is similar to an old situation that the designer has previously experienced. "It is our capacity to see unfamiliar situations as familiar ones, and to do in the former as we have done in the latter, that enables us to bring our past experiences to bear on the unique case. It is our capacity to *see-as* and *do-as* that allows us to have a feel for problems that do not fit existing rules".[95]

Third, the situations that the designer is engaged in a reflective conversation with exist in a virtual world. The virtual world enables the designer to experiment rigorously (in the sense developed in the first point above) by greatly reducing constraints which would prevent or inhibit experiment in the actual, built world. The virtual world serves as the context for the experiment within which a designer can suspend or control some impediment to reflection-in-action. Practice in the construction, maintenance and use of virtual worlds is a central part of the designer's expertise.

Reflection-in-action requires the designer to assume a stance towards inquiry that is different from that of a designer operating in the epistemology of technical rationality. In the model of technical rationality, the designer must maintain a clear boundary between herself and the object of inquiry. This is the stance of a "spectator/manipulator". The practitioner on the other hand, functions as an "agent/experimenter".[96] Schon posits the epistemology of technical rationality to be merely a small part of the more expansive epistemology of reflection-in-action.

---

uniqueness by Schon should be seen as being about the fact that problems or 'situations', while often similar, are never exactly the same.

[93] Donald A. Schon and Glenn Wiggins, "Kinds of Seeing and Their Functions in Designing," *Design Studies* 13, no. 2 (1992): 135–56.

[94] Schon, *The Reflective Practitioner: How Professionals Think in Action*, 155.

[95] Schon, 140.

[96] Schon, 163.

In reflection-in-action, being situated and seeking to transform this situation results in the production of knowledge that is objective in the sense that its truth can be confirmed or denied only within the designer's construction of the situation.

Yaneva and Latour: Mapping Controversies

Albena Yaneva, drawing on the work of Bruno Latour, has developed an understanding of design as mapping controversies. A controversy, in the sense that Yaneva sees it, is simply any "uncertainty that a design project, a building, an urban plan or a construction process undergoes; a situation of disagreement among actors over a design issue".[97] While she acknowledges that the reflection-in-action described by Schon is an essential part of design practice, she proposes that mapping controversies *about* design is an essential practice in the design studio. Following Latour, Yaneva sees buildings as "gatherings of many conflicting demands".[98] To understand architecture in the making, designers must look for controversies as they occur in the world, without deploying any meta-reflexive frameworks that may explain particular actions. This should be followed by a process of "mapping" these controversies. Mapping is "a self-exemplifying type of enquiry that deals with the consequences of the maneuvers of all actors involved in situations of uncertainty, their implications, their changing positions and opinions".[99] Such a map of controversies would involve all kinds of human and non-human actors – actors which are not meaningful individually but are relevant and meaningful only in the context of the networks that have been mapped. Yaneva refers to this process as a "mapping of the real".

The extent to which these mappings are possible is dependent on the media available to map them. In the example of the study of design of the third terminal to London's Heathrow airport, Yaneva's students use image galleries on the web, archives of the Heathrow developments, governmental papers, press clippings covering the community, and activists' protests and other materials to learn about the nature of dissent, to identify the actors and to follow the different events. This is the raw material that they use to familiarize themselves with the issues surrounding the project to learn what "design does", not what design is.[100] The mapping is carried out using software to "embed these actors into a representational space". This software ranges from "basic tools such as web page editors, Flash and Java, to 3D visual software, in accordance with the content that the students are dealing with." One of the goals of mapping is to produce "novel modes of visually incorporating controversy studies suited to a digital format".[101] So while "meta-reflexive" frameworks may not be involved in an attempt to produce meaningful maps of these controversies, the affordances of the media, the access to information in the public domain and the structure of the map itself do impose frameworks that shape what gets mapped and what doesn't.

The opposition that Yaneva sets up between the controversy mapping approach to *learn*

---

[97]Albena Yaneva, "From Reflecting-in-Action Towards Mapping of the Real," in *Transdisciplinary Knowledge Production in Architecture and Urbanism: Towards Hybrid Modes of Inquiry*, ed. Isabelle Doucet and Nel Janssens, Urban and Landscape Perspectives, v. 11 (New York: Springer, 2011), 122. For an extended account of case studies see Albena Yaneva, *Mapping Controversies in Architecture* (Burlington: Ashgate Pub. Co, 2012).

[98] Yaneva, "From Reflecting-in-Action Towards Mapping of the Real," 125.

[99] Yaneva, 123.

[100] Yaneva, 119.

[101] Yaneva, 123.

about design, and the reflection-in-action approach to *doing* design is perhaps overstated, to the extent that the controversy mapping approach must, out of necessity, involve on the part of Yaneva's students, an effort "to construct and impose a coherence of their own."[102] The controversies have not yet been mapped until they have been ordered into some coherent form. At the same time, while Schon's example of the student Petra and the instructor Quist may be a simple one which involves, as Yaneva puts it, a discussion about "materials and shapes", scholars Vinod Goel and Gabriella Goldschmidt have shown that especially with freehand sketches, it is possible to investigate a given problem in novel ways. In effect, the ambiguity and incompleteness inherent in both structure and the state of the sketch (at a given point in time) makes it possible to destabilize a problem, reconsider and rearrange its parts and introduce new ones into the picture.[103] In Yaneva's terms, one could argue that sketches afford the introduction of uncertainties into the design by permitting relationships to be destabilized, reconfigured, amended or appended. Sketches have their own liquidity.

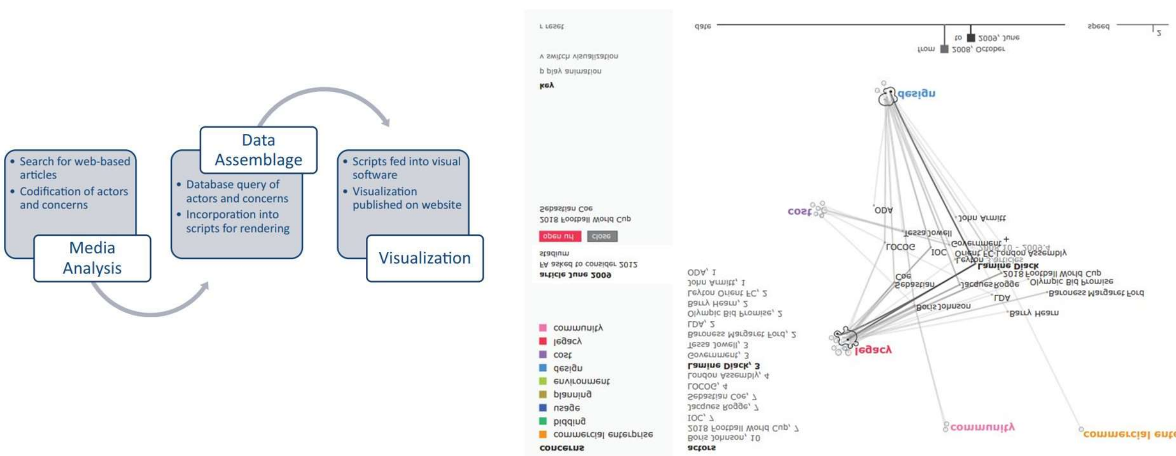


Figure 3 Yaneva's method of mapping controversies (left).[104] An example of a vizualization of a controversy mapping (right).[105]

Yaneva's method of mapping controversies can be considered a way of framing a design problem. Schon's approach is concerned with arriving at a design solution once the problem has been framed. In this sense, Yaneva's method could be considered as prior to Schon's approach. Once controversies have been mapped, a 'problem' can be framed and a representation of the solution (in Schon's example, a sketched plan and section) can be acted upon in reflective conversation. From what might be considered a standard point of view, this is not a controversial distinction. The architectural design problem is framed based on an extended survey of relevant concerns ("mapping controversies"). The architectural design solution is developed through a reflective conversation with a situation. This situation is a representation of these concerns using the appropriate medium.

However, the significance of Yaneva's contention that design is really mapping

---

[102] Yaneva, 126.

[103] See G. Goldschmidt, "The Dialectics of Sketching," *Creativity Research Journal* 4, no. 2 (1991): 123–43. and Vinod Goel, *Sketches of Thought* (Cambridge, Massachusetts: The MIT Press, 1995). This topic is discussed in greater detail in the next chapter.

[104] Yaneva, *Mapping Controversies in Architecture*, 91.

[105] Yaneva, 99.

controversies lies in the fact that from the Latourian standpoint, which Yaneva espouses, there are fundamental limits to our ability to represent problem situations if we wish to account for both matters of fact and matters of concern. Yaneva's approach involves mapping controversies because merely collecting facts is not possible. The facts are constantly disputed and hence situations are never available merely as collections of facts. As Latour put it in a keynote address to a design history conference in 2008: "In its long history, design practice has done a marvelous job of inventing the practical skills for drawing objects, from architectural drawing, mechanic blueprints, scale models, prototyping etc. But what has always been missing from these marvelous drawings (designs in the literal sense) are an impression of the controversies and the many contradicting stake holders that are born within these. In other words, you in design as well as we in science and technology studies may insist that objects are always assemblies, "gatherings" in Heidegger's meaning of the word, or things and *Dinge,* and yet, four hundred years after the invention of perspective drawing, three hundred years are projective geometry, fifty years after the development of CAD computer screens, we are utterly unable to draw together, to simulate, to materialize, to approximate, to fully model to scale, what a thing in all of its complexity, is. We know how to draw, to simulate, to materialize, to zoom in and out on objects; we know how to make them move in 3-D space, to have them sail through the computerized virtual *res extensa,* to mark them with a great number of data points, etc. Yet we are perfectly aware that the space in which those objects seem to move so effortlessly is the most utopian (or rather atopic) of spaces."[106] Latour concluded his talk with a question for designers: "[W]here are the visualization tools that allow the contradictory and controversial nature of matters of concern to be represented?" Latour rejected the post-modernist answer to this question, which is to dismantle the linear, objectified, reified modernist view through multiple viewpoints and heterogenous makeshift assemblages. Instead, he concluded, that what is needed instead are tools that capture what have always been "the hidden practices of modernist innovations: objects have always been projects; matters of fact have always been matters of concern."[107]

Latour understands design to be a "drawing together."[108] For Yaneva, designing involves collecting controversies, and mapping them. The representational forms in which these controversies are available cannot be limited at the outset. Any "visualization tools" (in Latour's terminology) which adequately represent controversies and make mapping possible should be extensible.

Discussion: Schon, Rittel and Yaneva/Latour

Starting from two very different points of view, the Yaneva-Latour position that design is mapping controversies and representing and resolving matters of concern, and not merely matters of fact, and Rittel's view that information is uneven and often internally irreducible and is better understood as a collection of issues, represent parallel objections and responses to the original systematic approaches. Schon frames the crisis in 'technical rationality' as a dispute about ends. This dispute renders instrumental problem solving to be ineffective because there is,

---

[106] Bruno Latour, "A Cautious Prometheus? A Few Steps toward a Philosophy of Design (with Special Attention to Peter Sloterdijk).," in *Networks of Design: Proceedings of the 2008 Annual International Conference of the Design History Society (UK)* (2008 Annual International Conference of the Design History Society (UK), University College, Falmouth, Cornwall: Universal Publishers, 2008), 9.

[107] Latour, 9.

[108] Bruno Latour, "Drawing Things Together," in *Collection* (MIT Press, 1990), 19–68.

yet, no problem to be solved. The task of framing the problem is a non-technical one. This is similar to the Latourian view that reality is available to designers, in significant part, as a collection of controversies. Yaneva's approach does not involve the claim that mapping controversies enables problems to be framed. Latour and Yaneva argue, separately, that what is needed is a way to represent controversies. Schon's proposal that problems are framed through a reflective conversation with the situation (represented in his example through the sketched floor plan and section). Designing progressed through a constant reframing of the problem. Yaneva's work can be seen as an advancement of Schon's work in the sense that she shows that in order to describe designing, the understanding of the design representation itself needs to be revised. Rittel's cryptic observation that a theory of design must be constituted as a theory of action of which a theory of knowledge must be a part also points in the same direction. The attention of Rittel, Schon and Yaneva's Latourian inquiry shifts from systematic step-wise problem solving, towards a detailed consideration of the machinery of architectural representations.

The conceptual basis for the systematic information processing approach to describing design was a fundamental conception of the way the human mind worked. The so-called 'computational theory of mind' posited that humans processed information about reality in the way that a computer does – through symbolic information processing. Computation thus formed the core metaphor not just for understanding designing as a purposeful human activity, but for understanding the cognitive processes of humans who undertook this activity. Recent scholarship in the philosophy and psychology of cognition has challenged this account of cognition. This challenge constitutes yet another basis for rejecting the systematic approach favored by Herbert Simon.

Cognition: Standard, Embodied, Situated

Cognition is defined in the Oxford English Dictionary as "the action or faculty of knowing."[109] As such, a theory of design cannot be posited without a theory of cognition underlying it. A theory of cognition would be a theory of how we know things in the world and about the world.

In the scholarship on human cognition, a distinction is sometimes made between cognition and perception. Cognition is seen as a higher-level activity – knowing, then perception, a lower level activity which is defined as the "process of being aware".[110] In this section, the concept of cognition is considered as it appears within cognitive science scholarship (broadly conceived) with specific reference to the human cognition of space, the human ability to solve problems and the human capacity for action. Action is addressed through a discussion of the concept of affordance proposed by the psychologist James Gibson, and widely influential in scholarship of human technology interaction, and on theories of how we humans make sense of our world.

---

[109] "Cognition, N.," *OED Online* (Oxford University Press), accessed July 28, 2018, http://www.oed.com/view/Entry/35876.

[110] The OED definition is available at "Perception, N.," *OED Online* (Oxford University Press), accessed July 28, 2018, http://www.oed.com/view/Entry/140560.. The distinction is made significantly in theoretical approaches which depend on a computational theory of mind. James Gibson, whose theory of affordances in discussed in this chapter, did not make a distinction between perception and cognition. Other approaches such as David Marr's computationalist approach, and Eleanor Rosch's work on categorization, make a clear distinction between these two activities. See Marr, *Vision*. And Eleanor Rosch and Barbara Bloom Lloyd, eds., *Cognition and Categorization* (L. Erlbaum Associates, 1978).

The central claim of "standard cognitive science" is that mental processes are algorithmic and involve operations on symbolic representations. These mental processes have definite starting and ending points, and since they begin with input to the brain and end with output from the brain, can be studied by limiting investigations to processes inside the head, without regard to the world outside. Inquiry in cognitive science occurs at a level distinct from the biological or neurological on the one hand, and the sociological and cultural on the other. This level of inquiry is sometimes referred to as the representational level of inquiry. The primacy of the computational metaphor enables a de-emphasis on the contribution of historical and cultural factors, as well as affective aspects such as emotions.[111] If one accepts the basic assumption of cognitive science – that the mind functions like a computer – then one has to assume that there are mental representations. These representations must be constituted by symbol systems. The structure of these symbol systems must be similar to the structure of thoughts. When the structure of thoughts changes, so must the structure of symbol systems used to represent those thoughts. Similarly, different symbol systems must invite differently structured thoughts. [112]

Over the past two decades, standard cognitive science has been challenged on three distinct fronts – embodiment, embedding and extension. The first claim – embodiment- relies on the assertion that cognition depends not just on the brain, but also on the body. This is to say that cognition is embodied. The second claim – embedding- asserts that cognitive activity routinely exploits the structure of the natural and social environment. This is to say that cognition is embedded in the environment. The third asserts that the boundaries of cognitive activity extend beyond the skin of individual organisms. This is to say that cognitive activity is extended and distributed in the environment in which it is situated. These three theses are the basis of the broad idea that cognitive activity is situated.[113]

Shapiro casts these challenges to the sweeping computational metaphorical basis of standard cognitive science in a different way. He terms the challenges in terms of three hypotheses – the conceptualization hypothesis, the replacement hypothesis and the constitution hypothesis. The conceptualization hypothesis states that the body of an organism limits the type

---

[111] See Gardner, *The Mind's New Science*. For a more recent account, from which I borrow the phrase "standard cognitive science" see Lawrence A. Shapiro, *Embodied Cognition*, New Problems of Philosophy (New York: Routledge, 2011). Shapiro uses the terms to distinguish "standard cognitive science" from "embodied cognition". The latter consists, for Shapiro of three hypotheses about the way humans engage with the world – conceptualization, replacement and constitution, as discussed in this chapter.

[112] This is the central argument deployed by Vinod Goel in his study of sketching in architectural design. See Goel, *Sketches of Thought*. It is also the central assumption of a large body of scholarship which draws on Schon's account of design as reflection-in-action towards understanding the role that different modes of external representation in architectural design. See Gabriela Goldschmidt, "The Backtalk of Self-Generated Sketches," *Design Issues* 19, no. 1 (2003): 72–88; Goldschmidt, "The Dialectics of Sketching"; IM Verstijnen et al., "Sketching and Creative Discovery," *Design Studies* 19, no. 4 (1998): 519–46.

[113] See Philip Robbins and Murat Aydede, eds., *The Cambridge Handbook of Situated Cognition* (Cambridge; New York: Cambridge University Press, 2009). for an extended survey of scholarship in this field. This scholarship recognizes the work of Varela, Rosch and Thompson on 'enactivism' – the view that the world is understood – cognition is possible - only due to embodied action, Clark and Chalmers on the 'extended mind' – the authors argued that the mind is constituted by active engagement with the environment, and Lakoff and Johnson's work on centrality of metaphor, and the reliance of metaphor on our embodiment, to our ability to have a society as important early statements. See Francisco J. Varela, Evan T. Thompson, and Eleanor Rosch, *The Embodied Mind: Cognitive Science and Human Experience*, New edition (The MIT Press, 1992)., Andy Clark and David Chalmers, "The Extended Mind," *Analysis* 58, no. 1 (1998): 7–19. and George Lakoff, *Metaphors We Live By* (Chicago: University of Chicago Press, 1980).

of concepts it can acquire. The replacement hypothesis states that cognition emerges as a property of the dynamical system comprising of an embodied organism and its environment. This is similar to the extension hypothesis but depends of using cybernetic, dynamical systems theory to replace symbolic information processing which is characteristic of standard cognitive science. The constitution hypothesis states that the constituents of cognitive processes extend beyond the brain – that the mind is literally constituted by the body, even extends beyond the body to include the world.[114]

While Shapiro develops his argument by explicitly privileging standard cognitive science and examining the merits of these hypotheses against it, the basis for many of these challenges precedes the development of standard cognitive science itself, and lies in the work of philosophers such as John Dewey, Ludwig Wittgenstein and Maurice Merleau-Ponty.[115] For the purpose of my present argument, it is assumed that cognition is inescapably situated, both by the capabilities of the body and the environment in which the body exists.

These objections to the standard cognitive science account of how the human mind works is significant for the present work because it supports the criticisms posed by Rittel (in particular). If the designing is concerned with addressing issues (Rittel), reframing problems (Schon) or addressing controversies (Yaneva), then the problem has already been complicated as far as the possible representation of the design proposal or design problems are concerned. The developments in the scholarship about human cognition discussed in this section suggest that the nature of these representations will significantly affect the extent to which humans are able to address these issues/controversies/problems. Rittel, Schon and Yaneva/Latour establish that design problems are not information processing problems (in the computational sense). Current accounts of cognition underpin these objections by suggesting that the mind does not operate as an autonomous information processing machine either. The way people make sense of the world depends on the machinery they have at their disposal to do this.

One way to examine the possibilities afforded to a human by the world is through the psychological concept of affordances. This is discussed in the next section.

Affordances and Cognition

The concept of "affordance" was introduced by the psychologist J. J. Gibson. Drawing on the work of Gestalt Psychologists like Kurt Koffka, Gibson defined an affordance of an environment as *"what it offers the animal, what it provides or furnishes."*[116] For Gibson, the affordance of an object was invariant. Gibson proposed his theory of affordances as a part of his broader cybernetic theory of direct perception.[117] Gibson did not strictly distinguish between

---

[114] This argument is also proposed by the cognitive anthropologist Edwin Hutchins. Hutchins studied pilots in airplane cockpits and captains guiding ships into port to show how cognition was distributed "beyond the skull of the individual", and constituted by a combination of the individual(s), instruments, instructions and other things involved in the work he observed. See Edwin Hutchins, *Cognition in the Wild* (Cambridge, Mass: MIT Press, 1995); Edwin Hutchins, "How a Cockpit Remembers Its Speeds," *Cognitive Science* 19, no. 3 (July 1995): 265–88.

[115] For a review, see Shaun Gallagher, "Philosophical Antecedents of Situated Cognition," in *Cambridge Handbook of Situated Cognition*, ed. Philip Robbins and Murat Aydede (Cambridge; New York: Cambridge University Press, 2009), 35–51. For Shapiro's account, see Shapiro, *Embodied Cognition*.

[116] Gibson, *The Ecological Approach to Visual Perception*, 127. See especially Chapter Eight "The Theory of Affordances".

[117] Gibson's theory can be considered to a computationalist theory as well, since it depended on an information-centric account of the relationship between animal and environment. Prof. Stephen Palmer made this argument

perception and cognition in his theory of ecological optics. Perception occurred due to active exploration of the environment by means of the Ambient Optic Array.[118] Affordances are embodied, but at the same time they are invariant properties of objects in the environment. He wrote *"One sees the environment not with the eyes but with the eyes-in-the-head-on-the-body-resting-on-the-ground."*[119] While affordances are invariant properties of the environment (they exist for a given observer whether or not they are perceived by this observer), they are neither subjective nor objective properties. They are a feature that reveals the inadequacy of the subject-object distinction. *"An important fact about the affordances of the environment is that they are in a sense objective, real, and physical, unlike values and meanings, which are often supposed to be subjective, phenomenal, and mental. But, actually, an affordance is neither an objective property nor a subjective property; or it is both if you like. An affordance cuts across the dichotomy of subjective-objective and helps us to understand its inadequacy. It is equally a fact of the environment and a fact of behavior. It is both physical and psychical, yet neither. An affordance points both ways, to the environment and to the observer."*[120]

Donald Norman adopted Gibson's concept for the context of Human-Computer Interaction (HCI) and modified it to account for "the perceived and actual properties" of the thing.[121] Norman's idea of making affordances a matter of perception, rather than a property of the object, as Gibson originally proposed, made the concept influential in studies of human-technology interactions.

The concept was adopted widely in HCI. Most recently, Kaptelinin and Nardi recently proposed a "mediated action perspective" based extension of Gibson's original concept. In doing so, the authors draw on Gibson's essential insight that we see the environment in terms of the range of action possibilities. The development of the concept from Gibson to Kaptelinin and Nardi involves a shift in the understanding of an affordance from an information-centric standpoint to an action-centric standpoint.[122]

Writing from the perspective of development of user interfaces and the doctrine of user-centered design, William Gaver argued that the central feature of affordances is that they directly

---

during a discussion. See also Stephen E. Palmer, *Vision Science: Photons to Phenomenology*, 1st ed. (The MIT Press, 1999).

118 The Ambient Optic Array referred to the light, structured by reflection of the earth, which was incident on the retina. This array of ambient light had the virtue of containing within it information about the world, as well as the relation of the observer to the world (by virtue of perspective). Gibson's ecological optics approach drew centrally from the insights of Claude Shannon's information theory. Perception was an active information processing event for Gibson. See Chapter 5 in Gibson, *The Ecological Approach to Visual Perception*.

119 Gibson, 221.

120 Gibson, 129.

121 Donald A. Norman, *The Design of Everyday Things*, 1st Doubleday/Currency ed (New York: Doubleday, 1990), 9. The book was originally titled 'The Psychology of Everyday Things'.

122 See Victor Kaptelinin and Bonnie Nardi, "Affordances in HCI: Toward a Mediated Action Perspective," in *Proceedings of the 2012 ACM Annual Conference on Human Factors in Computing Systems*, CHI '12 (New York, NY, USA: ACM, 2012), 967–976., Joanna McGrenere and Wayne Ho, "Affordances: Clarifying and Evolving a Concept," in *Proceedings of Graphics Interface 2000*, 2000, 179–186., William W. Gaver, "Technology Affordances" (ACM Press, 1991), 79–84; Auke J.K. Pols, "Characterising Affordances: The Descriptions-of-Affordances-Model," *Design Studies* 33, no. 2 (March 2012): 113–25; Paul Dourish, *Where the Action Is: The Foundations of Embodied Interaction* (Cambridge, Mass: MIT Press, 2001). especially Chapter 4 "Being in the world: Embodied Interaction" for a summary of the deployment of embodiment in human computer interaction.

connect perception and action. Affordances, for Gaver, are "properties of the environment relevant for action systems". This account of affordances depends on the existence of "perceptual information". In some instances, this information could be false, in others it could be hidden. The notion of a hidden affordance results from dependence on the two ideas, that affordances exist irrespective of perception, and that they are the result of the presence of perceptual information. Gaver is not clear about where this information is located – in the environment or in the person interacting in the environment. A vertical door handle, which afford pulling (as opposed to a horizontal one which affords pushing) may provide perceptual information which invites the action of pulling at the door. But this door could be locked, thereby making it impossible to successfully complete the action of pulling the door open. This is an example of a false affordance. I speculate that should the person in front of the door have never seen a door handle before, and or if the person is not culturally attuned to the idea that vertical door handles, then the affordance of the door handle in this instance is hidden. Gaver makes two additional classifications. He observes that affordances are sequential in time, and nested in space. For example, if the door handle was attached to the wall, it could not necessarily afford pulling. The affordance of the door handle is nested in the affordance of the door to be opened. The affordance of the door handle to be turned before it can be pulled is only evident once the door handle has been grasped. Gaver also reflected very briefly on the multi-sensory and multi-media nature of affordances.

McGrenere and Ho extend Gaver's concept by describing affordances along two dimensions – the ease of performing the action, and the clarity of information which indicates the action. The authors argue, in the context of developing software interfaces, that a good design would maximize both these features at once. In my example of the door handle, a handle which is easy to grip for the average person's hand and is easy to turn affords turning and pulling better than one which is not. Similarly, a handle with a small arrow pointing in the anti-clockwise direction, or (or together with) a small sign saying "Pull" which is easy to see, would provide clearer information. In McGrenere and Ho's view, these improvements would improve the affordance of the door, and the two dimensions along which these improvements fall, are two essential continuous dimensions of affordance.[123]

Gibson's concept of affordance relies on his idea of direct perception. An object in the environment "is what it is" for Gibson. In his appropriation of Gibson's idea, Norman no longer considered the affordance of an object to be invariant in the way of Gibson and Gaver. Once an affordance is a property of a relationship (the interaction between person and environment or object), and not of the object itself, the mediated nature of such relationships has to be taken into account. Kaptelinin and Nardi offer one approach by which this may be done. They do so by deploying a "mediated action perspective" and expanding and classifying the concept of affordance into two broad categories – instrumental affordances and auxiliary affordances. Technologies are situated between the person and the change the person is seeking to effect in the environment (Person – Technology – Object). Instrumental affordances are of two types – handling affordances (Person-Technology) and effector affordances (Technology – Object). In the example of the door, the door latch would be an example of the technology mediating the action of opening (or more specifically, pulling) the door. Handling affordances would refer to the affordance of the door handle, while effector affordances would refer to the affordance of the door (its hinges, its weight etc.). This is a simplified model of instrumental affordances. In most

[123] Diagram in McGrenere and Ho, "Affordances," 185. Should it be included?

real-life situations, it is possible to identify a chain of such instrumental affordances. The object of the relationship in one instance is the mediating technology in next. Auxiliary affordances are indirect affordances resulting from the existence of these chains (or webs in some cases) of mediators. For the purpose of the current study, the most relevant auxiliary affordance discussed by Kaptelinin and Nardi is a learning affordance. Most tools require a certain amount of training in order to be usable. This is true for modes of architectural representation such as sketching as well. What the pencil affords as a tool for sketching depends on the skill of the person using it.

Kaptelinin and Nardi have modified the gibsonian concept of affordance to account for the inherently mediated nature of socio-technical actions. Like Gaver, and McGrenere and Ho, their approach to developing the concept of affordance relies on classifying them. Where Gaver's classification is broken down along the dimensions of space and time, and McGrenere and Ho's classification is along the dimensions of information (for perception) and action, Kaptelinin and Nardi break down affordances according to a model of activity which considers it to be inherently mediated between one person and one object (in its simplest form).[124]

Affordances enable consideration of what the world offers the human. The human body has its own affordances. In other words, the human ability to perceive the world is itself a function of the affordances of the human body. The psychologist Barbara Tversky has argued that *"[c]ognition is inescapably affected by the immediate who, what, where, when and perhaps why."*[125] This situation of cognition in space and time makes possible the idea that bodies and the world have properties that afford, enable and constrain perception and action. These properties have "biasing effects on cognition" according to Tversky. She writes – *"We are upright creatures with three axes: an elongated, asymmetric head-to-feet axis that is aligned with gravity, which is a strong asymmetric axis of the world; and two axes that are not aligned with gravity, a front-back axis that is asymmetric, and a left-right axis that is for the most part symmetric. We have four mobile appendages, two legs that can move us preferentially in one direction on the ground, the direction we call "forward", and two arms that are free to manipulate objects in the world, preferentially in the forward direction. We have a set of sense organs oriented in the direction of movement."*[126]

The limits that exist due to the peculiar features of the body lead Tversky to distinguish three levels of spatial cognition. The first, most intimate level is the space of the body itself. This is the level at which parts of the body have to be aware of their co-location with respect to other parts. This co-location is essential to enable the body to perform simple tasks (such as catching a ball for example). The second level of analysis is the space immediately around the body – the immediate environment. This is defined as the space within reach of the hand or the eye. It determines the scope of potential perception and action and it is governed by the biases of the body itself. The third level of analysis is the space of navigation. This is conceptualized by Tversky as a space which is too large and possibly too complex to be perceived as a whole at once, and therefore must be constructed in parts. Maps, diagrams, drawings, three dimensional and virtual worlds are among the spaces which can be considered spaces of navigation. Tversky

[124] At the end of their paper, Kaptelinin and Nardi discuss the necessity of working out a taxonomy of affordances in a collective action as part of an agenda of future work.

[125] Barbara Tversky, "Spatial Cognition: Embodied and Situated," in *The Cambridge Handbook of Situated Cognition*, ed. Philip Robbins and Murat Aydede (Cambridge; New York: Cambridge University Press, 2009), 201–16.

[126] Tversky, 201.

and colleagues have found that people are prone to making systematic errors when it comes to these spaces of navigation. Such spaces of navigation enable cognition in various ways. They off load the contents of memory and make it available externally. This frees up working memory to work on external tokens (information, knowledge) rather than internal ones (that which is stored inside the head). This work can be the work of reorganization or reconceptualization. It can involve establishing new relationships between tokens. In Tversky account, cognition is inescapably spatial, situated and biased by the peculiarities of the human body.

Tversky's account is anticipated in many ways in Lucy Suchman's account of how people make sense of complicated machines like photocopiers.[127] Suchman studied how designers at Xerox Parc approached producing a user interface for a high-end feature-rich photocopy machine developed by the Xerox corporation. The intended approach was to create an intelligent expert system which would unfailingly guide users through a logical sequence of actions. The feedback they received from users who could not successfully use the machine with the help of this guide was that the user interface was too complicated and not user friendly. Suchman's study of users struggles and designers' intentions led to the conclusion that "human conversation does not follow the kind of message-passing or exchange model that formal, mathematical theories of communication posit. Rather, humans dynamically co-construct the mutual intelligibility of a conversation through an extraordinarily rich array of embodied interactional competencies, strongly situated in the circumstances at hand." Suchman found that the plans produced by the designers did not function as cognitive control structures (explicit, clear, unambiguous, logical sequence of instructions) for users confronted by the user interface. Users actions are not governed by prescribed, pre-ordained plans. Rather, they are constituted by the situation in which they occur through improvisation and situational responses.

However, people can get better at navigating spaces (to use Tversky's formulation). If people's actions are not governed by pre-ordained plans, but is often determined by local situational interactions within the constraints of what the navigation space afford the individual, then how does one explain this idea of getting better at navigating space? In the two-dimensional concept of affordances (information and action are the two dimensions) the information axis provides the clarity with which a particular action is indicated, and the action axis provides the ease with which this action can be performed. If the user's capability can be improved, this means that the affordance of the space can change. New actions can become possible and existing actions can become easier. What does it mean for an action to become easier? What does it mean for a new action to become possible? Dreyfus and Dreyfus developed a model of the development of expertise which provides one answer to how this might occur. This is considered next.

Conditioning Cognition and Affordances: Dreyfus's Account of Expertise

Hubert Dreyfus has developed an account of skill acquisition which explain the ability of people to acquire expertise in performing actions without considering this process to be a purely information centric one. For Dreyfus, expertise requires human embodiment. He explains this approach as a seven-stage process in its most recent form. I take the seven stages to serve an explanatory purpose, at least to the same extent that they constitute Dreyfus's theory of becoming expert at a skill. I explain this at length below, because Dreyfus's approach is one of the few that offers a theory of action which considers the role of the body and which considers

[127] Lucille Alice Suchman, *Human-Machine Reconfigurations* (Cambridge University Press, 2007).

the body to be inescapably necessary to explaining actions.[128]

Stage 1: Novice. Normally, instruction begins with the instructor breaking down the task into context-free features of the type that the novice can identify without knowing about the task. The instructor then provides rules based on these context-free features which form the basis of actions that the novice can perform in order to complete a given task. Dreyfus discusses three types of tasks – involving motor skills, intellectual skills and learning in the lecture hall. An example of a motor skill is learning to drive. When one learns to drive, one is asked to keep an eye on the speedometer needle and then shift from 1st to 2nd gear when the speedometer hits ten (say). A novice driver who knows how to read a speedometer, and who knows how to shift from first to second – using the clutch and the gear lever appropriately, can thus complete the task of shifting from first to second while driving. An example of an intellectual skill is learning to play chess. A novice chess player can be given a rule for determining the value of each piece on the chessboard, and the rules for how each piece can move. The novice can also be given a general rule saying that she should exchange pieces if the value of the pieces she gains in the exchange is greater than the value of the pieces she loses. In the classroom, the teacher provides the facts and the rules which a student needs to know in order to gain an understanding of a particular domain. The student learns to recognize features to which the given facts and rules can be applied through repeated practice.

Learning the rules about a given domain (be it driving a car, playing chess of gaining information from a lecture) is clearly not sufficient. On an incline, shifting too early may cause the car to stall. Doing so repeatedly and unnecessarily in heavy traffic may cause damage to the clutch system. Always following the rule about exchanges in chess will leave the novice open to sacrifices by the opponent. Merely learning facts and rules about a particular domain is also not enough, as these rules and facts are always context dependent. As a result, truly learning about the domain cannot be limited to successfully consuming information about it.

Stage 2: Advanced Beginner. After gaining some exposure to the use of given facts and rules in real situations (for example, driving on the street), the novice begins to become aware of contextual aspects of the facts and rules, and apply these contextual aspects alongside the non-contextual aspects learnt earlier. The driver learns to recognize the point at which gears need to be shifted based on the sound of the engine (if the motor sounds like it is racing, shift). The chess player learns situational aspects of the positions. These new types of rules are in fact more maxims than rules. While a rule is context-free, understanding and being able to apply a maxim requires that one already have some situational understanding of the domain in question (driving, chess etc.). In the classroom, only information is contextualized at this stage, so that the student can begin to learn the significance of the facts and rules supplied at the beginning (in the novice stage).

So far, learning is carried out in a detached analytic frame of mind, as the student follows

---

[128] Hubert Dreyfus has developed an extended phenomenological account of skill acquisition in Hubert L. Dreyfus and Stuart E. Dreyfus, *Mind Over Machine* (Free Press, 1988). which he co-authored with Stuart Dreyfus, an applied mathematician and industrial engineering professor at UC Berkeley. This section on a more recent account which extends the basic framework developed in Mind Over Machine in an argument about distance learning. See Hubert L. Dreyfus, "How Far Is Distance Learning From Education?," in *The Philosophy of Expertise*, ed. Evan Selinger and Robert P. Crease (New York: Columbia University Press, 2006), 196–212. The extended discussion in Evan Selinger and Robert P. Crease, eds., *The Philosophy of Expertise* (New York: Columbia University Press, 2006)., especially 193-244 and 302-321 is also used in this account.

instruction, is given examples in which those instructions apply, and begins to learn the significance of those instructions for the given examples (situations).

Stage 3: Competence. As the advanced beginner gains more experience, the number of potentially relevant facts and rules that have to be learnt in order to know most domains of learning quickly becomes overwhelming. This realization turns performing tasks into anxiety ridden, exhausting activities because any understanding of what is important is thus far missing. To cope with this overwhelming amount of information, students learn, through experience and instruction, to devise a plan, or to choose a perspective which can guide then on the question of what should be considered important and what can be set aside. Learning how to appropriately ignore large bodies of facts and rules learnt in the first two stages, makes it possible for students to complete tasks with competence as it makes them capable of coping with the overwhelming nature of both informational and situational volume and complexity. Just as the facts and rules (which can be learnt in a context-free sense, as a consumer of information) tends to grow exponentially, so does the number of new situations encountered.

Once this element of making choices about what to ignore and what to use is introduced, and plans or perspectives have to be chosen, the added anxiety of making a mistake enters the picture. In most skill acquisition domains (motor skills, intellectual skills or learning, to stay for the moment with the examples considered in this section), these choices have to be made to attain competence. The possibility of making a mistake, or failing, brings with it its own anxiety. Fear, elation, disappointment, discouragement are all results of the compulsory need to make choices. For example, a competent driver exiting the freeway learns to pay attention to speed, to making decisions about shifting gears. Based on a number of factors, the person may determine that she is going too fast, and subsequently, decide to step off the accelerator, or use the brakes to slow down. Successfully navigating exiting the freeway brings relief.

Dreyfus argues that "[i]f we were disembodied beings, pure minds free of our messy emotions, our responses to our successes and failures would lack this seriousness and excitement. Like a computer we would have goals and succeed or fail to achieve them but, as John Haugeland once said of chess machines that have been programmed to win, they seek their goal, but when it comes to winning, they don't give a damn. For embodied, emotional beings like us, however, success and failure do matter." He goes on to argue that going through emotional stress – the feeling of being frightened, elated, disappointed or discouraged, is an essential part of acquiring competence. "[R]esistance to involvement and risks" he writes "leads to stagnation and ultimately boredom and regression."[129] An individual who has reached the third level of skill acquisition is competent enough to realize that choices must be made about what is important in a given situation, and that these choices have consequences – they result in failure or success, or elation or disappointment. The competent performer is involved, not detached.

Stage 4: Proficiency. As the competent performer acquires the ability to discriminate among a variety of situations with involvement (as opposed to detachment), acting in these situations becomes progressively easier and less stressful. Proficiency is achieved through practiced competence. A proficient performer can see what needs to be done in each situation rather than using a calculative procedure to select one of several alternatives. Having acquired the ability to recognize the problem with proficiency, at this stage the performer does not yet can choose a response with the same proficiency. There are far fewer ways, argues Dreyfus, of

[129] Dreyfus, "How Far Is Distance Learning From Education?," 202–3.

seeing a situation than there are of working out responses to it.

The proficient driver, driving on a rainy day, may feel intuitively that she is approaching a curve too fast. She still must decide how to slow down – either by releasing the accelerator, or by pressing the brakes.

Stage 5: Expertise. Whereas the proficient performer who is immersed in the world of her skillful activity immediately sees what needs to be done, but must decide how to do it, the expert performer not only sees what needs to be achieved, she also sees immediately how to achieve it, thanks to her vast ability to make situational discriminations. The expert does the appropriate thing, at the appropriate time, in the appropriate way. The signature characteristic of expertise is an "immediate intuitive situational response."[130] To attain expertise, it is not enough to have practiced enough cases in each setting.

In his most recent iteration of his theory of skill acquisition, Dreyfus has added a 6th and 7th stage. The 6th stage provides an account of style. While this extension is important, it is not relevant to my account, so I will limit my discussion to Dreyfus's five basic stages of expertise.[131]

Dreyfus considers "expertise" to be far more fundamental to our existence in the world than is conventionally understood. This can be seen from the fact that Dreyfus does not distinguish between laypersons and experts, but between beginners and experts. Three clear distinctions can be drawn between beginners and experts in Dreyfus's account. First, the expert differs from the beginner because she no longer requires the deliberate use of context-free rules that are recognizable without experience to relate to a practice. The beginner on the other hand, can relate to a practice only due to access to context-free rules. Dreyfus has argued that this crucial distinction means that disembodied agents that rely on rules can only achieve competence, but not expertise. The second distinction is temporal. When making decisions about actions under consideration, the beginner slowly follows rules, the expert can make decisions in an intuitively situated way. The third distinction is an affective one. While the beginner is detached from the world in which he is acting, the expert is emotionally involved in the world in which she is acting. Expertise is not the ability to communicate information about a specific action. It is the ability to perform an action with a "thoughtless mastery."[132]

Summary

The action critique to the first-generation approaches to systematic design methods can be found in each of the critiques discussed in this chapter. Rittel not only argued that a theory of knowledge must be contained within a theory of action, he also showed that the unevenness of information was a central feature of design problems. Schon identified a crisis in ability of instrumental rationality to produce knowledge, and instead proposed a description of design in which each action reshapes the problem, and the types and possibilities of such action are governed by a local 'virtual world' created during the action. Schon did not develop the details of what this 'virtual world' might entail, and at any rate, did not anticipate the proliferation of technological augmentation of design activity which would be enabled by computers.

---

130 Dreyfus, 205.

131 Dreyfus first extended his account of skill acquisition in 2001 and 2008 in Hubert L. Dreyfus, *On the Internet*, 2nd ed. (Routledge, 2008).

132 Selinger and Crease, *The Philosophy of Expertise*, 217.

Yaneva’s Latourian approach involved a radical preference collecting controversies and mapping them irrespective of the representational forms this might involve. Whereas Schon and Rittel argued (in their separate ways) that the production of design knowledge is inescapably contingent on the types of action and the universe of possible actions, Yaneva’s proposals place the collection relevant controversies first and the possibility of mapping (‘mapping’ can be understood as the set of actions necessary to relate controversies to each other) them second. For Yaneva, knowledge is not just contingent on action, but the set of actions themselves must be contingent on the set of concerns.

These criticisms of the systematic methods-based approaches of the first generation drew attention to the contingent nature of designing and showed that the actions involved in designing could not be described as information processing. Such a description would, at best, be trivially abstract, and at worst, only describe a small subset of the possible types of actions. These criticisms also point to the importance of systems of architectural representation in design, and to the limits of these systems.

Contemporaneous to these criticisms of systematic methods, came criticism of the computational model of human cognition itself. These critical responses from fields in philosophy and anthropology show that the way we think is contingent on our body, on the environment in which we exist, and the tools, devices and mechanisms we use to live in this environment. The concept of affordance describes what an environment provides or furnishes to an individual. This concept was developed to be able to account for the idea that individuals can learn to exist (or do specific things) in an environment. Affordances change over time and they can change in specific directions. Dreyfus and Dreyfus show that these changes probably involve a restructuring of cognitive capability.

So far, the criticisms of systematic approaches bring forth the centrality of action and importance of the possible actions in the ultimate production of design knowledge. However, these criticisms did not develop specificities about the role of the representation for the designer. So far, if we consider the design act in its simplest form to involve a designer and a design representation (which is being modified, updated and improved during designing), then the criticisms to the first generation approaches show that the fact that access to the design representation is only possible in mediated form (mediated by the technology in which the representation is available), then the simplest design act can be described as shown in the figure below.

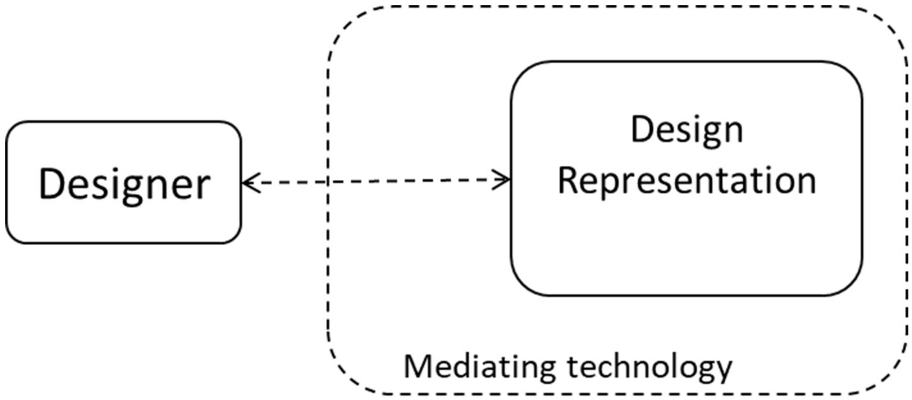


Figure 4 The Basic Unit of Design

However, this is not an adequate representation of the design act. It does not say anything about the medium, other than the fact that it exists. To develop this definition, the role of the representation in design, the influence of computing on architectural representation, and nature of architectural design representation itself needs to be considered. This is considered in the next chapter.

4. Computing, Representation and Immersion

Introduction

The theoretical developments discussed in the previous two chapters have been accompanied by parallel developments in computational support for various aspects of architectural practice. The advent of the personal computer has made computing ubiquitous in practice. Computer software is used to increase productivity and extend analysis in architectural design. This chapter considers the role of computing in architectural representation, with special emphasis on the early architectural design process.

Sketching is the most common mode of designing early in the process. It is preferred by designers when the design proposal is not well-formed enough to enable building a formal, measured three-dimensional model. Traditionally, sketching involves using a stylus to make marks on paper or vellum. Pencil, ink, charcoal and other types of stylus are commonly used while sketching. Recently, the term ‘sketch’ has been used more generally to refer to any system which enables ideas to be tested.[133]

Sketching (in its traditional sense) has also been the subject of significant research in its role as an architectural design representation. This research has contributed to the understanding of the cognitive role of the representation in architectural design. Recent technological advances have enabled computationally augmented sketching which have different affordances compared to those of the traditional mode. However, scholarship about the role of sketching in architectural design (and design in general) predates these technological advances and took place, in large part, during the same time as the developments in the theory of design methods discussed earlier. The consequences of these new affordances on the way sketching is understood as a design activity remain relatively unexplored.

The possibilities of technological augmentation of design representations, and representations of reality used in other fields (such as surgery) has resulted in the development of two related concepts – presence and immersion. These two concepts are discussed in this chapter to examine how they might extend the understanding of the role of the representation in early architectural design and how they might contribute to a theory of the design act which can account of technological variability.

This chapter begins with an overview of the role of computers in architectural representation. This is followed by a discussion of sketching as a representational mode in architecture and of attempts to technologically augment it. Presence and immersion are then discussed as concepts which illuminate the nature of technologically augmented representations. These areas allied with the discussion in the previous two chapters leads to a proposal for a model of the design act. This chapter concludes with a description of the Hybrid Ideation Space (HIS), an immersive sketching environment which seeks to augment the representational power of the design sketch by making it available at human scale in real time, so that the designer can

[133] For example, the Processing programming language for the visual arts refers to its integrated development environment (IDE) as a ‘sketchbook’ and each individual program as a ‘sketch’. See Casey Reas and Ben Fry, *Processing: A Programming Handbook for Visual Designers and Artists* (MIT Press, 2014). For an example of the use of Processing in a architectural context, see Kostas Terzidis, *Algorithms for Visual Design Using the Processing Language* (John Wiley & Sons, 2009).

be “in the sketch”.

The computer as architecture’s new machine

In 1975, Nicholas Negroponte of the Architecture Machine Group at MIT observed that the computer could potentially influence the responsiveness and individuality of living environments. This could be done by using the computer to assist, augment and eventually replicate the design process. Negroponte wrote that each experiment “removes the architect and his design function more and more from the design process; the limit of this progression is giving the physical environment the ability to design itself, to be knowledgeable, to have an autogenic existence. The general assumption is that in most cases the architect is an unnecessary and cumbersome (and even detrimental) middleman between individual, constantly changing needs and the continuous incorporation of these needs into the built environment. The architect’s primary functions, I propose, will be served well and served best by computers.”[134] Considering the subsequent demise of the research program in “strong AI” it is tempting to dismiss Negroponte’s radicalism. It is also tempting, as Negroponte acknowledges it might be, to read this as an anti-architect view. However, the radicalism of Negroponte’s position arises from his view that not only should design be systematic and rational, but that buildings should be conceived as a computer in some limited sense, as a machine which can respond and adapt to needs as these needs change.

When the object of the design problem and the process involved in solving the design problem can be understood through the same cybernetically inspired conceptual lens, it is not difficult to imagine future architects being permanent consultants to buildings which could be understood as adaptive machines which require maintenance and upgrades. Responsive façades which adapt to the direction of the sun, the time of the day, the day of the year and the shape of the surrounding built environment to optimize indoor daylight already exist.[135]

Computational feedback is central to the building systems which manage water, electricity, wireless networks, sanitation, security, thermal comfort, daylighting and other essential services which constitute the building of today. Their design depends on the use of Building Information Models (BIM) which enable a common model of buildings which can be used by the ever-increasing number of specialist consultants who are required on building projects.[136] In architecture the computer has now become pervasive to an extent that neither can be easily imagined without computational support. Even though limitations to the computability of design are increasingly well understood, design practice is constituted by an ever-increasing set of computable aspects.[137] The Building Information Models are based on the *Industry*

---

[134] Negroponte, *Soft Architecture Machines*, 1.

[135] The New York Times building in New York City by *Renzo Piano Building Workshop* features an adaptive screen developed by *Loisos + Ubbelohde.* See details here http://www.coolshadow.com/consulting/new_york_times.html

[136] Charles Eastman, “University and Industry Research in Support of BIM.,” Report on Integrated Practice (American Institute of Architects, 2006), http://www.aia.org/SiteObjects/files/2_Eastman.pdf.

[137] This was the central concern of a conference in the mid-1980s bearing the title ‘Computability of Design’. See Kalay, *Computability of Design*. In their conclusion Bruce Majkowski and Yehuda Kalay made the following distinction between design processes and computable processes “Design is an ill-defined process that relies on ill-understood practices such as learning, creativity, and intuition, as well as the judicious application of scientific principles, technical information, and experience. Computable processes, on the other hand, are by definition well-understood and subject to precise analysis and mathematical modeling, which qualify them for simulation by artificial computing devices” (p. 349-350) Efforts to achieve systematic definitions of design which could make it

Foundation Class (IFC) data model infrastructure.[138] This data model provides a standard description of building elements and mechanisms to extend this model with new data and rules. For example, if an innovation in approximating how temperature changes inside a building during the day is made, this innovation could be tested on any IFC compliant BIM platform. BIM is an extensible platform by which computational analysis of an ever-increasing variety of aspects of architectural design problems and projects can be evaluated.

This increasing pervasiveness of computation into the architectural profession, design practice and the built environment itself has resulted in scholars identifying digital turns and the rise of a digital culture in architecture.[139] The computer is understood to lie at the center of a paradigm shift in the profession which rivals that which occurred with the advent of printing, linear perspective and orthogonal drawing.[140]

Yehuda Kalay has identified three generations of CAD systems in the history of Computer Aided Design (CAD) in architecture. The first generation in the 1970s saw a two-pronged development in industry (a geometric modeling-based approach) and the academy (a building specific approach). Whereas development in industry responded to the industrial need for computer systems that could assist engineers in drawing complex geometries using Boolean operations and assessing manufacturability by planning milling machine paths and sheet metal folding tolerances, development in academy focused on systems of building description and space planning which could, using one database and one software package, support all building related operations. These included systems of parametric building description and tools that

more amenable to computable processes have been large unsuccessful, except when it comes to specific, computable sub-problems of architectural design. New techniques of considering energy use, water use, ventilation and other mechanical and structural problems have centrally impacted the results of architectural design, but do not support the view that design is computable.

138 The IFC infrastructure is managed at http://www.buildingsmart-tech.org/

139 See Picon, *Digital Culture in Architecture*; Mario Carpo, ed., *The Digital Turn in Architecture 1992-2012*, AD Reader (Chichester: Wiley, 2013).

140 This paradigm shift has been conceptualized differently by scholars espousing different perspectives. Chastain, Kalay and Peri propose that the paradigm shift can be understood in two distinct ways. The “square peg in a round hole” approach involves using new media to perform roles which in turn have been constituted by older media – the use of the new medium is misdirected in this case. An example of this would be the early use of computer aided design software for the narrow purpose of drafting plans and working drawings. The second approach is that of the “horseless carriage”, in which the new medium is understood in terms that have been made familiar through older media. In this second approach, the authors echo Marshall McLuhan’s claim in Marshall McLuhan, *Understanding Media: The Extensions of Man* (McGraw-Hill, 1964). that the content of any medium is another (usually earlier) medium. See T. Chastain, Y. E. Kalay, and C. Peri, “Square Peg in a Round Hole or Horseless Carriage? Reflections on the Use of Computing in Architecture,” *Automation in Construction* 11, no. 2 (2002): 237–48. In a more recent, historicist argument, Mario Carpo identifies the paradigm shift occurring due to the advent of computing as the end of the Albertian paradigm of architectural design. Carpo understands the Albertian paradigm to be an authorial, humanist practice of design away from the building site which depends on the architect’s intentions being faithfully, and identically replicated on the site. Carpo has less to say about what the new paradigm includes. His focus is on defining the paradigm which has been replaced. However, he does identify ‘distributed authorship’ and ‘variability’ to be two essential aspects of the emerging new paradigm. See Mario Carpo, *The Alphabet and the Algorithm*, 1st ed. (The MIT Press, 2011). Mark Wigley and others have described the ongoing shift as a shift towards a more networked idea of practice. In this, they seem to agree with Carpo, but Wigley, especially, traces a longer more gradual shift back to technological and organizational advances made during the Second World War and the influence of the ekistics of Constantinos Doxiadis. See *Network Practices: New Strategies in Architecture and Design*, 1st ed (New York: Princeton Architectural Press, 2007). Especially see Wigley’s essay *The Architectural Brain* in this volume. See also Mark Wigley, “Network Fever,” *Grey Room* (2001): 82–122.

could support habitability analysis, energy analysis and building specification verification analysis. These first-generation efforts in the academy anticipated, and were conceptual exemplars of, contemporary Building Information Modeling (BIM) tools which today dominate professional architectural practice.

In the 1980s, in what Kalay classifies as the second generation of CAD systems, improved processing power and display technology paradoxically resulted in "dumber" software. While first generation systems were designed to be building design systems, the second-generation systems were overwhelmingly conceived as drafting and modeling systems. Third generation systems were characterized by an effort to build intelligence into computer models. These systems were like the first-generation system and took advantage of advances in computer software development centered around object-oriented programming and artificial intelligence, database management systems and were designed to be design tools, and not just tools for making representations.[141]

The computer as a medium has influenced the design process in almost all its constituent parts. Conventionally, the architectural design process is divided into five phases – feasibility, early design (or conceptual design), detailed design development, construction and occupancy.[142] Computer systems have been conventionally aimed at the detailed design development and construction phases. These phases are typically distinguished by the level of precision, detail and resolution of the model. The design at the end of conceptual design phase tends to be worked out in limited detail, but usually consists of several important decisions. The design at the end of the detailed design phase consists of a detailed, fully worked out model of the design based on which construction drawings can be developed.[143] New technologies (CAD, BIM tools) have also had the effect of re-organizing these phases. The conventional expectation that a design will go from being more abstract and unresolved to being more notational and resolved as one goes from the early design phase to the detailed design phase is no longer always true. In the case of many specialized design projects like public elementary schools for example, technologies like BIM allow designers to use libraries of designed objects and detailed specifications provided by the client to begin their designs from a series of alternatives. Firms which specialize in specific types of architectural projects use this approach. Parametric models also allow the creation of alternatives by experimenting with various combinations of values for a given set of parameters. Buildings and built environments can be modeled at high levels of abstraction using such parametric models.

The use of computers is most pervasive in the detailed design phase of an architectural design project. It is at this phase where the design is well defined enough for the computer's ability to compute and store information reliably at high speeds is most useful. It is also at this phase that the most intensive collaboration with specialist consultants and contractors takes place, and a common model for collaborative work is most useful, given currently available architectural design software. Building Information Models are most useful during this phase.

---

[141] See Kalay, *Architecture's New Media*, 67–75..

[142] See Eastman, *Building Product Models*. Professional bodies which govern the profession in India, the US and the UK recommend that architects bill for services based on these phases.

[143] This taxonomy is also apparent in the way architectural design studio projects in architecture schools are organized. Typically, there are either desk crits or "pin-up" reviews at the end of each phase, or even multiple times for each phase.

These analyses of the role of computers in architectural design do not involve an analysis of how the computer, as a medium, shapes the possibilities of inquiry in architectural design. Negroponte and Kalay view the computer as becoming ever more pervasive not only in the design activity but in the built environment itself. Negroponte predicted that the computer would assist, augment and eventually replace the architect. In 2006, in a review of the impact of information technology on the design professions, Kalay observed that as an "information-centric enterprise", architectural design had been revolutionized by the revolution in information processing brought about the availability of ubiquitous personal computers, the internet and networking technology. Kalay sees the impact of the revolution in information processing in collaboration (both within the discipline of architecture and across the various specialist disciplines whose involvement is essential in architectural projects), in building automation, and in virtual place making.[144]

In the last 30 years of the 20th century, the use of computers in architecture was explicitly classified for the purposes of generation, evaluation and communication of architectural design ideas and models. This classification is a direct result of the early iterative models of design discussed in the previous section. Generative technologies (such as parametric geometric modeling software) have enabled architects to conceive of physical forms which would have been not only extremely difficult to conceive and visualize in the past but also prohibitively expensive to construct.[145]

Relatively less attention has been paid to the potential influence of computers in the early design process. Recent developments in the area of virtual place making and immersive CAVE technology are indicative of a larger recognition of the limits of the computational metaphor of design. The consideration of the computer as a medium – as a machine that mediates our understanding of the world, and specifically, of the architect's understanding of the problems and opportunities of architectural design projects – is still in very early stages. In this area, the greatest advances have been made in the field of augmenting the process of sketching.[146]

Sketching in architectural design

External design representations made by architects on two-dimensional planes can broadly be classified into three distinct types. This classification is based on the stage of the process in which they are prevalent and the audience for which they are prepared. The three categories of drawings are sketches, presentation drawings and working drawings (sometimes also referred to as construction drawings). Presentation drawings are usually prepared for clients or fellow architects and are used when the design is at an advanced stage and much of the

---

[144] Yehuda E. Kalay, "The Impact of Information Technology on Design Methods, Products and Practices," *Design Studies* 27, no. 3 (May 2006): 357–80. The areas of interdisciplinary collaboration and virtual place making have been the focus of the Digital Design Research Group headed by Prof. Kalay in the Department of Architecture at UC Berkeley.

[145] The architectural projects of Frank Gehry became possible due to the use of the modeling software CATIA, which was originally developed to design airplanes. See H. Bredekamp et al., *Gehry Draws*, ed. M. Rappolt and R. Violette (MIT Press in association with Violette Editions, 2004). The architect Greg Lynn explicitly credited parametric modeling software with making new architectural geometries possible. See Greg Lynn, *Folds, Bodies & Blobs: Collected Essays* (Bruxelles: La Lettre volée, 1998).

[146] See Johnson et al., "Computational Support for Sketching in Design." for an extended review of developments in computational support for sketching. The authors trace a history which begins with Ivan Sutherland's Sketchpad device which was developed in 1963.

conceptual and formal design work has been completed. Working drawings or construction drawings are dimensionally precise orthogonal drawings which are made to communicate information about the construction of the proposed built environment. These include detailed construction dimensions, specifications for materials and construction methods and a schedule of components. In most jurisdictions, working drawings are legal documents and must adhere to legal requirements. Sketches typically occur early in the design process when decisions have not been reached to the point where a well-formed model of the design proposal is possible. This tripartite classification of visual representations is commonly accepted in architectural design studio. It has also been identified in other disciplines such as engineering design. Gabriela Goldschmidt refers to sketches made during architectural design as "idea-sketches".[147] The current discussion is limited to this class of sketches.

Sketching emerged as a practice in design since paper of sufficiently good quality became available plentifully and cheaply available because of the printing revolution in Europe in the 15th century. Gutenberg's invention of movable type generated a demand for paper.[148] While this paper was originally manufactured for printing documents, it was also used to make sketches as seen by the sketches of Leonardo da Vinci and Michelangelo. The scholarly literature on sketching in design and idea generation more generally has emerged, in the main, since the 1970s. Before the 1970s private sketches (sometimes referred to as 'doodles') made by architects were typically not catalogued and stored in the way presentation drawings, measured drawings and scale models were. This changed as scholarly interest shifted from design methods (as seen in the demise of the Design Methods movements in chapter 2) to design processes, practices and thinking. The British architect James Stirling's private design sketches were published in architecture magazines in the 1970s. The architect Frank Gehry's sketches were collected and published in book form. The private design sketch has emerged as a significant part of design culture.[149]

Daniel Herbert was among the first to study the properties of sketches, which he called

---

[147] Eugene Ferguson distinguishes between the 'prescriptive sketch', the 'talking sketch', and the 'thinking sketch'. The prescriptive sketch specifies dimensions and other attributes of an entity. Even though it is a freehand drawing, its purpose is specification. The purpose of the talking sketch is communication with clients, consultants, reviewers or colleagues. The thinking sketch is made for private purposes, to communicate with oneself. See Eugene S. Ferguson, *Engineering and the Mind's Eye* (The MIT Press, 1994). For Goldschmidt's contribution, see Goldschmidt, "The Dialectics of Sketching." See also G. Goldschmidt, "Serial Sketching: Visual Problem Solving in Designing," *Cybernetics and Systems* 23, no. 2 (1992): 191–219.

[148] For a detailed account of the print revolution, see Elizabeth L. Eisenstein, *The Printing Press as an Agent of Change*, First Paperback Edition, vol. (Vol 1 and 2) (Cambridge, UK: Cambridge University Press, 1980). The field of architectural design was also influenced by this process. Printing played a central role in the dissemination of architectural design theory. See Mario Carpo, *Architecture in the Age of Printing: Orality, Writing, Typography, and Printed Images in the History of Architectural Theory* (The MIT Press, 2001).

[149] Goldschmidt attributes the emergence of interest in sketches in part to the rise of postmodernism in the 1970s. The example of James Stirling's sketches is drawn from Goldschmidt's work. See Gabriela Goldschmidt, "Modeling the Role of Sketching in Design Idea Generation," in *An Anthology of Theories and Models of Design*, ed. Amaresh Chakrabarti and Lucien T. M. Blessing (London: Springer, 2014), 433–50. Frank Gehry's sketches were collected in Bredekamp et al., *Gehry Draws*. Monographs about his projects also feature his design sketches prominently. See for example C. van Bruggen, *Frank O. Gehry: Guggenheim Museum Bilbao* (Guggenheim Museum Publications, 1998).

architectural study drawings.[150] In distinguishing study-drawings from presentation drawings, Herbert made the following observation - "While the public nature of presentation drawings typically requires graphic refinement and permanence, study drawings are graphically rough and informal . . . . . . and are almost immediately superseded by some new study drawings".[151] Herbert goes on to discuss five properties of study drawings. These five properties are labeled by Herbert as "Hidden Structure", "Gaining Information", "Graphic Conventions", "Continuity and Change" and "Drawings as Metaphors". In these five properties, Herbert addressed issues of abstraction and its implications for the information being communicated, the existence of graphic conventions, even though the drawings are not made for external consumption, the dual requirements of continuity (in terms of memory) and change (in terms of new ideas), and the role of study drawings as graphic metaphors. Herbert's study lays out some important factors in the study of sketches. Fish and Scrivener proposed a theoretical model of the role of sketching in artistic invention. In this model they propose that the sketch facilitated the translation of propositions into depictions and vice versa.[152]

Goldschmidt adopted Rudolf Arnheim's pioneering arguments against the separation of perception and thinking in psychology[153] and showed that while designing using sketches, ideas are developed through interaction between the visual display of the sketch and mental images which are enabled by the sketch. In this sense, sketching during design can be considered a search for imagery.[154] Elsewhere she argues that "designers continually reason about prospective features of the designed entity and the rationale for accepting or rejecting them."[155] They do this by generating 'interactive imagery' about the design using the sketch as the device to think with.[156]

---

[150] See Daniel M. Herbert, "Graphic Processes in Architectural Study Drawings," *Journal of Architectural Education* 46, no. 1 (1992): 28–39; Daniel M. Herbert, "Study Drawings in Architectural Design: Their Properties as a Graphic Medium," *Journal of Architectural Education* 41, no. 2 (1988): 26–38.

[151] Herbert, "Study Drawings in Architectural Design: Their Properties as a Graphic Medium," 26–27.

[152] J. Fish and S. Scrivener, "Amplifying the Mind's Eye: Sketching and Visual Cognition," *Leonardo* 23, no. 1 (1990): 117–26.

[153] For Arnheim's broader argument about "visual thinking" see Rudolf Arnheim, *Visual Thinking*, 1st ed. (University of California Press, 1969); R. Arnheim, "A Plea for Visual Thinking," *Critical Inquiry* 6, no. 3 (1980): 489–97. For the purposes of the current argument, visual thinking can be considered to occur in two ways. First, external visual stimuli such as a photograph or a drawing could serve as an inspiration for developing a mental image about the design problem under consideration. This could be considered a passive form of visual thinking. Second, the visual stimulus is developing during the consideration of the design problem itself, usually by sketching it.

[154] Goldschmidt, "The Dialectics of Sketching."

[155] Gabriela Goldschmidt, "Cognitive Economy in Design Reasoning," in Human Behaviour in Design (Springer, Berlin, Heidelberg, 2003), 53.

[156] The exact nature of the mental image is the subject of philosophical debate. Within the current context, Finke proposed that three broad approaches to understanding the nature of mental image are available. 'Structural' theories propose that mental images have the same spatial and pictorial properties of the physical object which is being imaged in the mind. 'Functional' theories propose that mental images are formed (and modified or updated) to contribute to the recognition and categorization of the physical object being imaged in the mind. 'Interactive' theories propose that mental images are constructed as part of concurrent perceptual processes. In other words, the expectation of seeing an object influence the mental images of the object. See Ronald A. Finke, "Theories Relating Mental Imagery to Perception," *Psychological Bulletin* 98, no. 2 (September 1985): 236–59. More broadly, the mental imagery debate spans the broad fields of philosophy and psychology. See Nigel J. T. Thomas, "Mental

Goldschmidt conducted a protocol analysis study of a sketch based architectural design process.[157] In her study, Goldschmidt rebuilt the architectural design process that she observed during the study in terms of "moves" and "arguments". A move is defined as "an act of reasoning which presents a coherent proposition pertaining to an entity that is being designed", while an argument is an "a rational utterance made by a designer and bears on the designed entity or an aspect thereof."[158] Goldschmidt found that the interactive mental imagery associated with sketching during the architectural design process consisted of two modalities – "seeing as" and "seeing that". When a designer is "seeing-as", she is using figural, analogical reasoning, while when the designer is "seeing-that", she is using non-figural, discursive reasoning. The process of sketching according to Goldschmidt, is "systematic dialectics between the 'seeing-as' and 'seeing-that' reasoning modalities". A diagram outlining this dialectic of sketching is shown in the figure below.

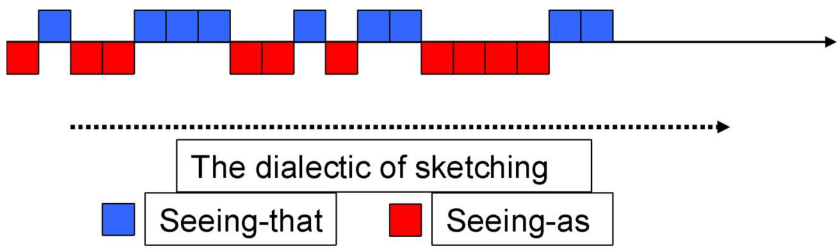


Figure 3 The dialectics of sketching[159]

Goldschmidt thus makes the distinction between a layman's sketch and a "design-sketch" or an "idea-sketch" by highlighting the descriptive, non-figural aspects of the design-sketch and its part in the dialectic of sketching. The purpose of the sketch is not so much to depict what the designer sees, but it is to create a visual display which will help induce mental images about the proposed design. Earlier, Jill Larkin and Herbert Simon had shown earlier that two-dimensional diagrams, by being located on a flat plane, were more "computationally efficient" than sentential representation of the same information (this is one dimensional as a sentence must be read as a linear sequence of words). The improved cognitive efficiency of diagrams compared to sentences is due to the diagram's ability to display information which is typically only implicit in sentences.[160] However, Larkin and Simon were concerned with the use of these representations for problem solving tasks. Design problems are not always available in a form which is amenable to being 'solved'. Further, Larkin and Simon assumed that the mind operates essentially like a computer, and hence their explanation of the advantages of the diagram were limited to the idea

---

Imagery," ed. Edward N. Zalta, *The Stanford Encyclopedia of Philosophy* (Metaphysics Research Lab, Stanford University, 2017), https://plato.stanford.edu/archives/spr2017/entries/mental-imagery/.

[157] See Goldschmidt, "The Dialectics of Sketching." Protocol Analysis is a method of analyzing records of design activity. For a general discussion of the method, see Karl Anders Ericsson and Herbert Alexander Simon, *Protocol Analysis: Verbal Reports as Data* (MIT Press, 1993). For the use of Protocol Analysis in architectural design research, see Nigel Cross, Henri Christiaans, and Kees Dorst, eds., *Analysing Design Activity*, 1st ed. (Wiley, 1997).

[158] Goldschmidt, "The Dialectics of Sketching," 125.

[159] This diagram is based on diagrams prepared by Goldschmidt. Goldschmidt, 132–36.

[160] To use the terminology of computer programs, this study showed that data structures can make programs more efficient. For example, a binary tree is a more efficient data structure for a sorting operation than a linked list. In the same way, Larkin and Simon showed that a diagram on a two-dimensional plane is more efficient than a one-dimensional (or sequential) sentence. Jill H. Larkin and Herbert A. Simon, "Why a Diagram Is (Sometimes) Worth Ten Thousand Words," *Cognitive Science* 11, no. 1 (1987): 65–100.

that the diagram enabled more efficient computation. Goldschmidt's cognitive account, on the other hand, developed a dialectic between an internal (mental) image and the external (observable) sketch. Goldschmidt's study provided a systematic account of how sketching enabled designs to develop and opened the possibility of more detailed studies which helped to elaborate further properties of design sketches and their relevance to designing.

One significant example of the detailed inquiries under this model of a dialectic between a mental image and a visual display relates to a debate about the importance of the interactivity of the visual display itself. It is possible to develop design concepts by relying exclusively on visual imagery alone without needing to sketch and update the visual display as Bilda and Gero, and Athavankar and his colleagues have shown.[161] This idea is a descendent of the notion of 'mental synthesis' developed by Finke and colleagues.[162] To examine the possibilities of mental imagery, Finke and colleagues devised an experiment in which they showed participants 15 shapes (some abstract geometrical shapes like a square, others where common objects like bracket or hook), each identified by its name. After the participant had memorized the shapes, these were taken away and the participant was blindfolded. The participant was then told the names of three of the shapes, chosen at random. The task for the participant was to combine these shapes into a new object which fit a given category (for example, a toy) over a period of 2 minutes. The blindfold was removed, and the participant sketched the object and explained what it was. Nearly all participants could complete this task. Further, most participants first combined the shapes and then decided on specifying what the resulting object was, and not the other way around even though a goal object type was specified. Andersen and Helstrup repeated this experiment but added a control group whose members could sketch during the two minutes.[163] They found that sketching did not improve results compared to the blindfolded participants. Mental imagery has been shown to be a powerful cognitive tool. In other words, a lot of progress can be made if one is skilled of manipulating mental images.

However, there are limits to capabilities of mental imagery. Verstijnen and her colleagues showed that while mental images worked well for tasks involving combination or recombination of elements into new arrangements, when the problem involved restructuring elements themselves prior to combining (or recombining) them, sketching improves performance significantly.[164] Sketching enables restructuring because it provides implicit connections (as identified by Larkin and Simon) between explicitly drawn elements, and even between the drawn figure and the background.

Goel identified three important symbolic characteristics of sketches.[165] Sketches are abstract (graphical representation involves the use of simpler symbols to represent complex and

---

[161] Zafer Bilda, John S. Gero, and Terry Purcell, "To Sketch or Not to Sketch? That Is the Question," Design Studies 27, no. 5 (2006): 587–613; U Athavankar, "Mental Imagery as a Design Tool," in Proceedings of the Thirteenth European Meeting on Cybernetics and Systems, vol. II (Thirteenth European Meeting on Cybernetics and Systems, Vienna, Austria: Austrian Society of Cybernetics and University of Vienna, 1996), 382–87.

[162] R Finke, *Creative Imagery: Discoveries and Inventions In Visualization* (Hillsdale: Erlbaum, 1990); Finke, "Theories Relating Mental Imagery to Perception."

[163] R.E. Anderson and T Helstrup, "Visual Discovery in Mind and on Paper," *Memory and Cognition* 21 (1993): 283–93.

[164] Verstijnen et al., "Sketching and Creative Discovery"; I. M. Verstijnen et al., "Creative Discovery in Imagery and Perception: Combining Is Relatively Easy, Restructing Takes a Sketch," *Acta Psychologica* 99, no. 2 (1998): 177–200.

[165] Goel, *Sketches of Thought*.

detailed configurations of parts), ambiguous & vague (they enable multiple interpretations, without necessarily enabling any great depth of specification), and imprecise (in scale and proportion). In these observations, Goel echoes Herbert. Further, the immediacy of the act of sketching enabled these characteristics. These properties of sketches, according to Goel are important enablers of creativity. They enable "lateral transformations in the solution space".

In his study, Goel used sketching to show that the computational theory of mind, which required human thought processes to be precise, rigid, discrete and unambiguous, could not give an account of sketching, as sketches were constituted by symbol systems which are dense, ambiguous and amorphous, and as such, not computably accessible.[166] Goel shows that not only is sketching possible despite the fact that sketches are constituted by symbol systems which are not amenable to computation, the ambiguous nature of marks made in sketching is especially useful to the purpose of sketching. Goel's work represents a radical challenge to the computational theory of mind and shows that cognitive processes are not only possible outside the strictures of this theory but can achieve ends which symbolic information processing cannot.

This brief account of scholarship whose aim was to define and describe sketching establishes the design-sketch (henceforth, sketch) as a specific type of mark making activity which is essential in designing as it supports the development of ideas by allowing marks to be made quickly, contingently, informally. Goldschmidt and Goel challenge the conventional computational theory of mind in different ways. Goldschmidt's challenge arises because she shows that sketching during design follows Arnheim's conception of visual thinking rather than standard information processing account in which the senses provide data and the mind processes data. Goel's challenge arises because he shows that ambiguous nature of the symbol system deployed during sketching enables designers to read more into sketches than is present in them.

The skill of the designer plays a role in potency of the sketch-based design process. Suva and Tversky compared students and professional architects developing designs using sketching and found that professional architects were more skillful at transformative reasoning ('seeing-as' in Goldschmidt's terms, 'lateral transformations' in Goel's terms) when it came to functional questions.[167]

This brief review of studies of sketching in design reveals a consensus about the unique value of sketching. Sketching is used to store, reorganize, restructure and extend ideas and influence the cognitive economy of designing. Further sketches are especially useful design representations because they can externalize ill-formed, imprecisely categorized and inter-related ideas. The ease and speed with which sketches can be made, remade and superseded contributes to their cognitive efficiency. Since they are not prepared for public communication of ideas, sketches are minimally bound by public conventions of drawing or annotation, they can remain

[166] Goel uses Nelson Goodman's theory of symbol systems in his account. See Nelson Goodman, *Languages of Art: An Approach to a Theory of Symbols*, 2nd ed. (Indianapolis: Hackett Publishing Company, 1976). Sketches are constituted by dense, ambiguous and amorphous symbol systems in a goodmanian sense. A sketch consists of infinitely many distinct marks. In other words, given any two marks which are made in a sketch, a third mark which is neither one or the other already defined mark is always possible. Further, the marks are semantically vague and ambiguous and in many cases, semantically overloaded.

[167] Architects were able to read non-visual functional issues from sketches with greater facility. This is, interestingly, not n Masaki Suwa and Barbara Tversky, "What Do Architects and Students Perceive in Their Design Sketches? A Protocol Analysis," *Design Studies* 18, no. 4 (1997): 385–403.

as complete or incomplete as the designer wishes, and can be repeated, modified or transformed using translucent sketch paper with speed and easy. Private styles, methods and conventions for sketching can be developed, providing further cognitive efficiency.

Computational support for sketching has aimed to augment the capacity of the sketch to provide cognitive assistance to designers by enabling easy control and manipulation of color, thickness, transparency and style of the marks being made by the stylus, by providing the ability to recognize and in some cases complete what the user is trying to draw, and by providing means to manage ambiguity. This last feature is one of the oldest features in computer aided design and is found in Ivan Sutherland's pioneering Sketchpad system.[168] Computational support for sketching spans sketching done for all purposes (not only design), and a detailed discussion of this subject is beyond the current scope.[169]

Presence and Immersion

Marvin Minsky used to the following example to explain his concept of telepresence. "You don a comfortable jacket lined with sensors and muscle-like motors. Each motion of your arm, hand, and fingers is reproduced at another place by mobile, mechanical hands. Light, dexterous, and strong, these hands have their own sensors through which you see and feel what is happening. Using this instrument, you can "work" in another room, in another city, in another country, or on another planet. Your remote presence possesses the strength of a giant or the delicacy of a surgeon. Heat or pain is translated into informative but tolerable sensation. Your dangerous job becomes safe and pleasant."[170] Remote control tools, which enabled a person to work remotely in another place were typically described as teleoperators, but Minsky preferred the terms telepresence because the term presence, to him emphasized the high quality of sensory instruments which would feel and work like the user's hands so that no significant difference would be noticed between the use of the instruments and the use of the hands.[171]

Minsky idea contributed to the development of the field of teleoperators and telepresence within the broader field of human-computer interaction, in large part through the journal *Presence: Teleoperators and Virtual Environments.* Of central concern to this scholarship has been the question of defining and if possible, measuring the nature of virtual or 'tele' presence, or at least tele operation. Presence has been understood to be a subjective sensation. Thomas Sheridan proposed a three-dimensional definition of this subjective sense of presence. For Sheridan, presence is constituted by the extent of sensory perception, the ability of the user to control the relationship of the sensor to the environment, and the ability of the user to modify the

---

[168] I.E. Sutherland, "SketchPad: A Man-Machine Graphical Communication System.," in *AFIPS Conference Proceedings*, vol. 23, 1963, 323–28.

[169] An extended discussion of the current trends in computational support for sketching is available in Johnson et al., "Computational Support for Sketching in Design."

[170] M. Minsky, "Telepresence," *Omni* 2, no. 9 (1980): 45.

[171] The concept of 'presence' predates Minsky, for instance, in the fields of cinema theory (in the work of the theorist Andre Bazin) and in sociology in the work of Irving Goffman, who defined the term co-presence to describe the idea that a person who is co-located with another is aware that she is being perceived in whatever she is doing, including her experience of others. HIS is designed to promote synchronous local and remote co-presence as well as remote presence in general, but since collaborative design has been set aside, the idea of a remote presence is relevant. The discussion from cinema theory is excluded. See Erving Goffman, *The Presentation of Self in Everyday Life*, 1st ed. (Anchor, 1959)., and Andre Bazin, *What Is Cinema?*, trans. Hugh Gray, vol. 1, 2 vols. (University of California Press, 1968).

physical environment.[172] Lombard and Ditton proposed that presence is "the perceptual illusion of non-mediation" in which "a person fails to perceive of acknowledge the existence of a [human-made] medium in their communication environment and responds as if the medium were not there."[173] This notion of illusion is a steady component of most definitions of presence. The International Society for Presence Research (ISPR) defines presence as "a psychological state or subjective perception in which even though part or all of an individual's current experience is generated by and/or filtered through human-made technology, part of all of the individual's perception fails to accurately acknowledge the role of the technology in the experience. Except in the most extreme cases, the individual can indicate correctly that s/he is using the technology, but at *some level* and to *some degree*, his/her perceptions overlook that knowledge and object, events, entities and environments are perceived as if the technology was not involved in the experience. Experience is defined as a person's observation of and/or interaction with objects, entities, and/or events in his/her environment; perception, the result of perceiving, is defined as a meaningful interpretation of experience."[174]

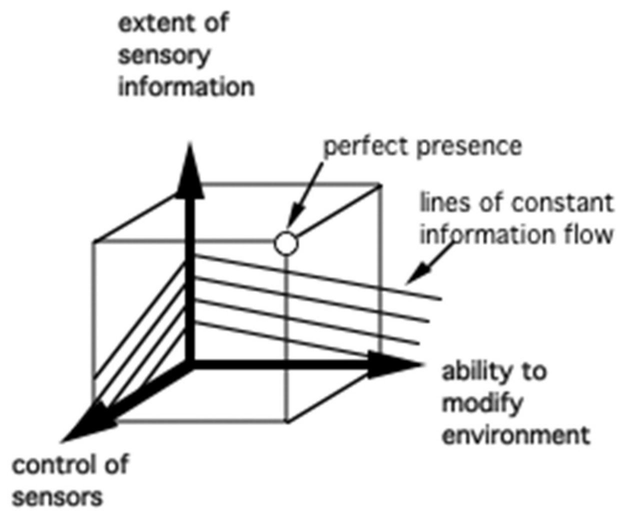


Figure 5 Sheridan's three-dimensional conception of presence[175]

Spatial presence is a special type of telepresence and is typically defined as the subjective experience of being physically located in a mediated space. Spatial, in this sense, involves a direct reference to the physical human scale. For instance, a telephone conversation may create illusion that one is co-present with the interlocutor, but it is not an illusion of spatial presence.

Immersion has been defined as the extent to which a technology can produce a sense of telepresence. While presence refers to the subjective experience of the user, immersion is a property of the mediating technology. Slater and Wilbur define immersion as "the extent to which the computer displays are capable of delivering an inclusive, extensive, surrounding and vivid illusion of reality to the sense of a human participant."[176] The extent to which a mediating technology is inclusive has to do with extent to which physical reality (the participants actual

---

[172] T. B. Sheridan, "Musings on Telepresence and Virtual Presence," *Presence: Teleoperators and Virtual Environments* 1, no. 1 (1992): 120–26.
[173] Lombard and Ditton, "At the Heart of It All: The Concept of Presence."
[174] This definition is available of the ISPR website at http://ispr.info/about-presence-2/about-presence/
[175] Sheridan, "Musings on Telepresence and Virtual Presence," 121.
[176] Slater and Wilbur, "A Framework for Immersive Virtual Environments (FIVE)."

physical surroundings) are shut out. The extent to which mediating technology is extensive has to do with the range of sensory modalities accommodated (sight, hearing, smell, touch, taste). Surrounding has to do with the extent to which the mediating technology is panoramic, rather than being limited to a narrow field. Surrounding is primarily a visual property, thought spatialized surround-sound can contribute to the extent to which a mediating technology can contribute to a sense of presence. Vividness has to do with the resolution or fidelity offered by the mediating technology.

Immersion requires the existence of a virtual body – an object which represents the user within the technologically mediated representation. If the sense of presence is spatial, then this representation of the user should be at eye-level with reference to the technologically mediated representation. Additionally, there should be reasonable matching between the actions of the user and corresponding actions of the representation of the user in the technologically mediated representation. For example, when the user turns her head to the left, the view of the virtual space should reflect this. The extent to which the mediating technology enables this contributes to the extent to which the mediating technology is immersive.

The twin concepts of immersion and presence, as they apply to the technology and the user respectively, form part of a specialized body of scholarship within human-computer interaction. There is a scholarly consensus on the major factors influencing spatial presence. Spatial presence is enhanced in highly immersive media environments because presence is enhanced when the user's attention is completely or substantially captured. The body of the user must be appropriately embedded within the virtual world. Appropriate embedding has to do not just with the physical scale of the virtual world, but also with the correlation of the movements and actions of the body with movements and actions in the virtual world. Interaction enhances the sense of presence, if the interaction is error free.[177]

While immersion and presence are useful concepts for understanding technologically mediated representations of spatial environments, the literature suggests that these concepts have been developed to understand the extent and nature of the sense of presence. This literature does not address the question of the desirability of a given extent and nature of presence.[178] This question cannot be addressed without reference to a specific domain. This fact also limits the applicability of the definitions of presence and immersion to domains beyond the field of human-computer-interaction or technological mediation itself. However, the twin concepts of immersion and presence offer a framework for developing concepts applicable to specific domains. In the next section, this is done for the domain of architectural design.

Immersion in Architectural Design Representations

Extending the basic framework described in the summary conclusion of the previous chapter, the design representation can be said to be of the design at the site as it exists at a given point in the design process (and to the extent that it exists), and one or more versions of the design as it should be. At the outset, the designer's engagement with a representational medium

[177] Tilo Hartman et al., "Spatial Presence Theory: State of the Art and Challenges Ahead," in *Immersed in Media: Telepresence Theory, Measurement & Technology* (Springer International Publishing, 2015), 115–35. For a recent review of scholarship about the relationship between immersion and presence, see Slater, "Immersion and the Illusion of Presence in Virtual Reality."

[178] An overview of the current state of scholarship on telepresence is available here. Matthew Lombard et al., eds., *Immersed in Media: Telepresence Theory, Measurement & Technology* (Springer International Publishing, 2015).

(or mediating technology) is assumed. In other words, when the designer wakes up in the morning and is drinking coffee, the designer is not considered to be 'designing', even though this morning coffee make occur between a late night at the work desk and an early morning return to the work desk. The designer is understood to exist in one of two distinct states with reference to a specific representational medium – using the medium or not using the medium. The figure below describes a state in which the designer is using the representation medium.

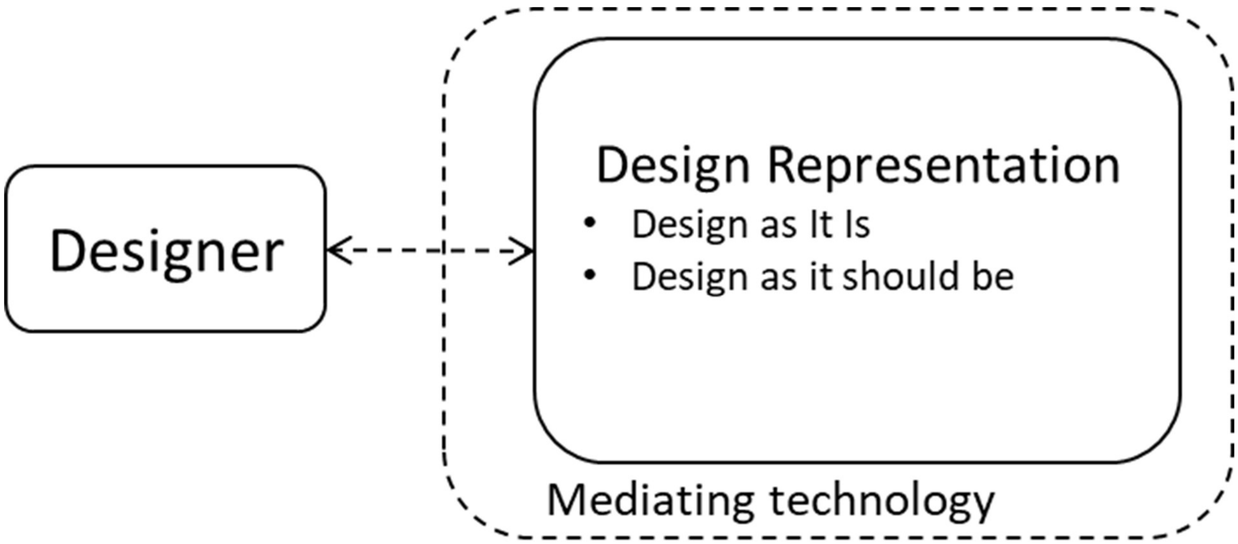


Figure 6 Basic provisional framework of the design act

However, it is undeniably the case that the designer's access to the design problem, the design site and the design solution(s) is so far as they exist at a given point in the process, is not limited to what is available within the current representational technology. Further, the designer can use or at least refer to this extra knowledge while designing. This knowledge is not located in the design representation, nor is it available in unmediated fashion. It is the designer's accumulated memory or expertise (for the current argument, these terms apply interchangeably). This is referred to as contextual knowledge, or, context. Context is like the role played by 'long-term memory' and 'external environment' in Simon's schema of the design process.[179] In Simon's schema, these two repositories provide the input for reshaping the problem space and preparing a new well-formed problem. This is done to resolve the difficulty of problems being 'ill-structured'. In the current paradigm, which seeks to model the act first (and does not assume that the idea that the act involves information processing renders the details of the act trivial as far as describing the design process is concerned) and considers the production of knowledge to be derivative of this act, the inter-relationship between design, design representation and context, and the ways in which these three elements inform and transform each other is constituted by the capacities of the mediating technology, the skill or expertise of the designer and capacity of the mediation to admit contextual knowledge.

---

[179] Simon, "The Structure of Ill Structured Problems," 193.

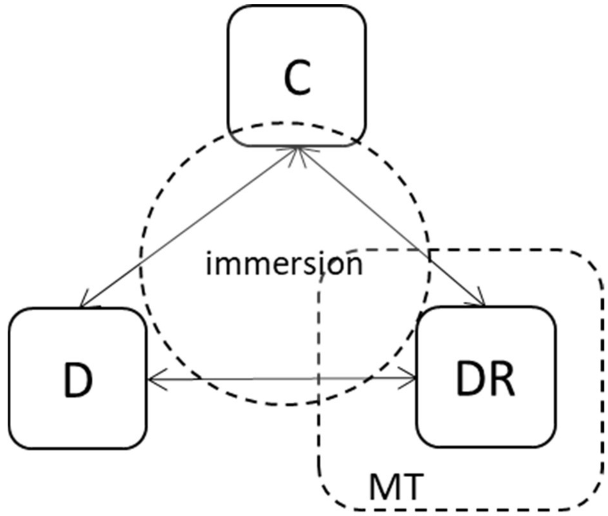


Figure 7 D: Designer, DR: Design Representation, MT: Mediating Technology, C: Context

As seen in the previous section of this chapter, the concepts of immersion and presence have been developed in the fields of human-computer interaction and telepresence such that immersion is a property of the technology which creates an illusion of presence. These concepts have been developed to describe and measure the extent to which a mediating technology facilitates the illusion (or perception) of being in a virtual world. In the context of architectural design, the problem is complicated by two facts. First, the designer's interest in the design representation is to transform it. This entails accessing aspects which are available within the representation, as well as facts about the design problem (or design situation) which is available beyond the representation. Hence, in architectural design, an important feature of the immersive capabilities (using immersion in the conventional sense from the telepresence literature) of the mediating technology is the extent to which it enables the architect to switch back and forth. But this ability to switch back and forth can be reasonably considered to depend on the designer's skill or expertise, and on the extent and relevance of contextual knowledge available to the designer.

In the context of architectural design, a distinction has been made between immersive and non-immersive representational systems. Immersive systems are those which totally surround the user, while non-immersive systems do not and are sometimes described as 'window-on-a-world' systems.[180] However, three dimensional representations of space are instrumentalized representations of space.[181] Geometrical systems of representing space are rationalized representations, be they orthogonal or perspectival.[182] The use of two dimensional sections, and

[180] Jennifer Whyte, *Virtual Reality and the Built Environment*, 1st edition (Oxford: Routledge, 2002); Marc A. Schnabel and Thomas Kvan, "Spatial Understanding in Immersive Virtual Environments," *International Journal of Architectural Computing* 1, no. 4 (December 1, 2003): 435–48.

[181] The idea that 3d representations are not natural but are systematic geometrical constructions has been problematized by scholars influenced by phenomenological approaches. For a discussion of the problems arising out of these instrumentalized representational modes on creativity and design in general see Alberto Perez-Gomez and Louise Pelletier, *Architectural Representation and the Perspective Hinge*, 1st ed. (The MIT Press, 2000); D. Vesely, *Architecture in the Age of Divided Representation: The Question of Creativity in the Shadow of Production* (Cambridge, Massachusetts: MIT Press, 2004).

[182] William M. Ivins, *On the Rationalization of Sight* (Da Capo Press Inc, 1976). This rationalization has been seen

plans, and three dimensional axonometric drawings has been standard in architectural design practice for at least half a millennium. Axonometric drawings provide the so-called "god's eye view" (simply put, the ability to see both sides of the wall at once) and offer a different system of rationalizing space compare to visual perspective. In a perspective representation, the user's eye can be located at a specific spatial point in relation to the objects in the space. This point can be located by its three-dimensional position. In an axonometric representation (or for that matter, in a two-dimensional plan or section), the user is putatively positioned "nowhere".

This approach to comparing perspective and axonometric systems underlies, in-part, the distinction between immersive and non-immersive representational modes. The scalar relationship between the user's body and the representation contributes to the perception of being present (as does the correspondence between the user's bodily movements and the representation, as seen in the previous section of this chapter). But both axonometric and perspective systems enable scaling, or, in other words, allow the representation to be transformed meaningfully with reference to the user's field-of-view. Therefore, rather than considering representational systems through a binary immersive/non-immersive lens, it is better to consider different representational systems to be offering different degrees and types of immersion. The nature of immersion is dependent on the nature of the design act, the type of problem being considered, and the type of representation involved and the way in which it is involved.

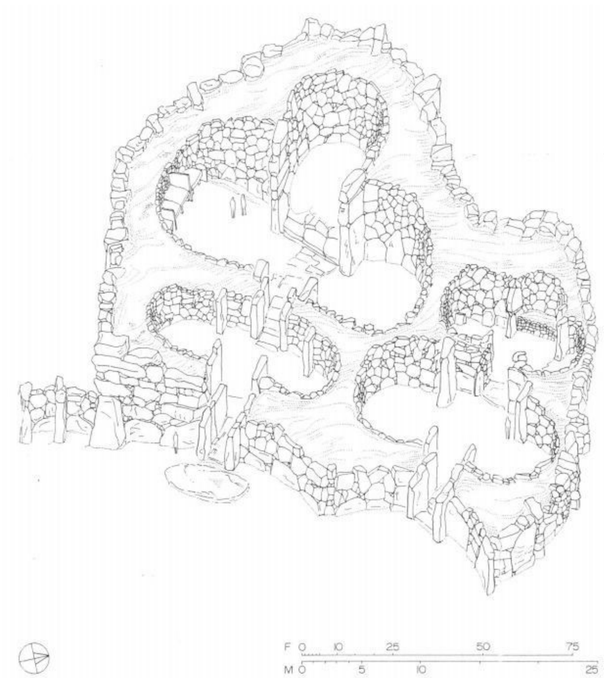


Figure 8 An example of a cutaway axonometric (oblique) view of Gjantija, a Neolithic temple complex in Malta. Drawing by Richard Tobias for Spiro Kostof's Architectural History textbook[183]

---

as a symbolic form of an historical epoch, as representative of a mode of organizing and presenting knowledge which came to constitute a historical age. Erwin Panofsky, *Perspective as Symbolic Form*, trans. Christopher Wood (Zone Books, 1993). Patrick Maynard has argued that drawing and drawing systems constitute a fundamental toolkit by which people make sense of the world. For Maynard, drawing is an autonomous philosophical form. Patrick Maynard, *Drawing Distinctions: The Varieties of Graphic Expression* (Ithaca, N.Y: Cornell University Press, 2005).

[183] Spiro Kostof, *A History of Architecture: Settings and Rituals*, 2nd ed. (Oxford University Press, USA, 1995), 34.

In the context of the design act, immersion cannot be localized as a property of the mediating technology, and presence cannot be localized as a property of the user. The architect's encounter with the representation is purposeful – the intention is the modify or transform the representation. This transformative purpose mandates the conceptual reevaluation of immersion and presence as they have been developed in the human-computer-interaction and telepresence literature. The illusion of presence is only relevant in architectural design representation as far its influence on the design act. Hence the term immersion is proposed as a property of the design act itself. It describes the nature of the three-way relationship between designer, design representation and context, and is influenced by the designer's skill, the extent and nature of contextual information, and the affordances of the mediating technology. While human scale may be privileged due to the domain under consideration, it cannot be considered independent of the affordances of the mediating technology.

The Hybrid Ideation Space

The Hybrid Ideation Space (HIS) is an immersive, real time sketching environment developed at the *HybridLab*, University of Montreal by Prof. Tomas Dorta and his colleagues. It was designed as an augmented sketching environment in which sketches could be made and simultaneously inhabited by collaborating participants, at first locally and then remotely using a shared representation.[184]

The basic apparatus of the Hybrid Ideation Space consists of a tablet computer mounted on a stand which enables the computer to be rotated 360 degrees along an axis vertical to the ground. The computer is connected to a digital projector and is situated within a hemispherical screen. The designer draws on a tablet in a software which contains a picture background of an immersive spherical projection of the design site. The image is projected in real time onto the hemispherical screen. With appropriate calibration, this provides an adequate illusion of being and sketching "at the site". At any given time, a specific segment of the hemispherical projection is available on the screen. By rotating the tablet, the screen can be accessed by parts. The system can be extended by connecting two devices at different location in a network for two designers to collaborate remotely. The connection is achieved by providing a shared "site" which can be sketched on in real time from both locations. For example, in a design session conducted collaboratively by one user in Montreal and one user in Berkeley, both users could share and develop the same sketch at the same 'site'. This is known as synchronous remote collaboration. While collaborative design is not within the scope of the present research project, it is an important aspect of HIS and is the purpose for which the HIS was originally developed.[185] The

[184] In addition to the published material on this technology and research conducted using this technology, I base this section on multiple discussions and interviews with Prof. Dorta. See Dorta, "Augmented Sketches and Models: The Hybrid Ideation Space as a Cognitive Artifact for Conceptual Design."

[185] While the HIS was initially developed as a tool for augmenting ideation during design (See Tomas Dorta, "Ideation and Design Flow Through the Hybrid Ideation Space" (Sigradi MX 2007, Mexico City, 2007), 418–22. Dorta., and Dorta, "Augmented Sketches and Models: The Hybrid Ideation Space as a Cognitive Artifact for Conceptual Design.") recent work has been focused on collaboration. See Tomas Dorta, Annemarie Lesage, and Edgar Perez, "Point and Sketch: Collaboration in the Hybrid Ideation Space," in *Proceedings of the 20th International Conference of the Association Francophone d'Interaction Homme-Machine* (IHM 2008, Metz, France: ACM, New York, 2008), 129–36., Tomas Dorta et al., "Signs of Collaborative Ideation and the Hybrid Ideation Space," in *Design Creativity 2010*, ed. Toshiharu Taura and Yukari Nagai (London: Springer, 2010), 199–206., Tomas Dorta et al., "Design Conversations in the Interconnected HIS," in *Collaborative Management and Modelling for Design* (EuropIA.13: 13th International Conference on Advances in Design Sciences and Technology,

system is still in its experimental stages. Its development has been shaped by its developer's interest in collaborative design ideation in both local and remote settings.

A designer working in the HIS stands in front of a tablet computer monitor set horizontally on a turntable. The turntable can rotate over 360 degrees. The designer can sketch on the tablet screen using a stylus. The marks made by the designer are recorded by means of the HIS software, which also provides a user interface. This interface enables the designer to sketch using different colors, different line thicknesses and different degrees of transparency in the line. The ability to change thicknesses allows the same stylus to be used to fill a shape on the screen as well as to draw on it. The designer can also undo previously drawn lines in the sequence in which they have been drawn. Being an early sketching tool, the system does not enable the classification and organization of lines into logical classes. For example, it is not possible in the current system to organize or classify marks into classes or objects in the way that this can be done in a Building Information Model or a surface modeling system. The designer 'moves' within the 'site' by using the zoom or pan facilities. The zoom facility enables the designer to focus on a smaller segment of the spherically projected 'site' by zooming in, and on a larger segment of the site by zooming 'out'. The pan facility works in alliance with the turntable. Whereas the turntable allows the designer to pan horizontally in the site, the pan facility allows the designer to pan vertically in the site. The system also allows the designer to save records of stages in the design, either by manually saving screenshots of the 'site', or by setting an auto save function which can record screenshots are regular intervals to a given location on the computer's memory. The HIS software is installed on the Macintosh operating system and a video of the screen can be recorded using a combination of video software and the Skype remote chat system. In the current version of the HIS software, a blackboard is also available. This is a black rectangular surface which can be invoked during the design, to allow the designer to work outside the site. The blackboard can be moved around in the site. Sketches on this blackboard can also be saved in the same way as the immersive sketches.

The figure below shows a diagrammatic comparison of sketching in the Hybrid Ideation Space (B) and conventional sketching with a pencil or pen on paper. A mark made by a designer in the Hybrid Ideation Space can potentially be visible in two places simultaneously – on the tablet in the partial view of the immersive sketch, and in the immersive sketch itself. The mark can only be made on the tablet. The surface on which the immersive sketch is made cannot be directly marked. When the system is used by two designers in a collaborative design setting, one designer can use a laser pointer to point to issues in the designer, while the other can use the stylus to modify or add marks to the design.

The first preliminary observation can be made immediately about the issue of scale. Contemporary 3D modeling systems are advertised as enabling design at 1:1 scale in the "model space."[186] When one considers a designing in an immersive space, it immediately becomes clear

Rome, Italy: Europia Publishers, Paris, 2011), 83–93., and Tomas Dorta et al., "Comparing Immersion in Remote and Local Collaborative Ideation through Sketches: A Case Study," in *Proceedings of the 14th International Conference on Computer Aided Architectural Design*, ed. Pierre Leclerq, Ann Heylighen, and Martin (Designing together: CAAD Futures 2011, Liege: Les Éditions de l'Université de Liège, 2011), 25–39.

[186] The "model space" is a term used by Autodesk's AutoCAD drafting tool since its earliest versions in the early 1990s. Model space is distinguished from "paper space". The latter is the drawing it will appear on paper, to a specified scale which will fit on the paper. The former is the same of the model where true dimensions can be used instead of their corresponding scaled down measurements.

that such a true 1:1 scale is available differently for a designer who is trying to understand a model of a building or a site, and a designer who is trying to modify or add to the model of a building or a site. Human beings are limited by reach of their arms and the size of their bodies in what they can draw. The HIS operates different as an immersive environment when it comes to understanding a design, as opposed to modifying the design. A significant research and engineering opportunity exists in trying to design media which change the terms of these two modes of immersion. While this question is beyond the scope of the present project, it is one avenue for research in the future. However, the possibility of two distinct modes of immersion also means that the designer must switch back and forth between such modes. Switching between these two modes involves switching between being immersed in the 'site' and being immersed in the HIS.

The second preliminary observation can be made about the sense of perspective. When sketching on the tablet, the boundaries of the tablet are clearly visible to the designer as they lie within her cone of vision. When the designer looks up from the tablet to the site projected around her, this boundary is significantly weakened. The experienced HIS user is immediately aware of the marker on the immersive screen indicating the section of the screen, which is visible on tablet, but the marker does not constitute the boundary of what the designer can see.

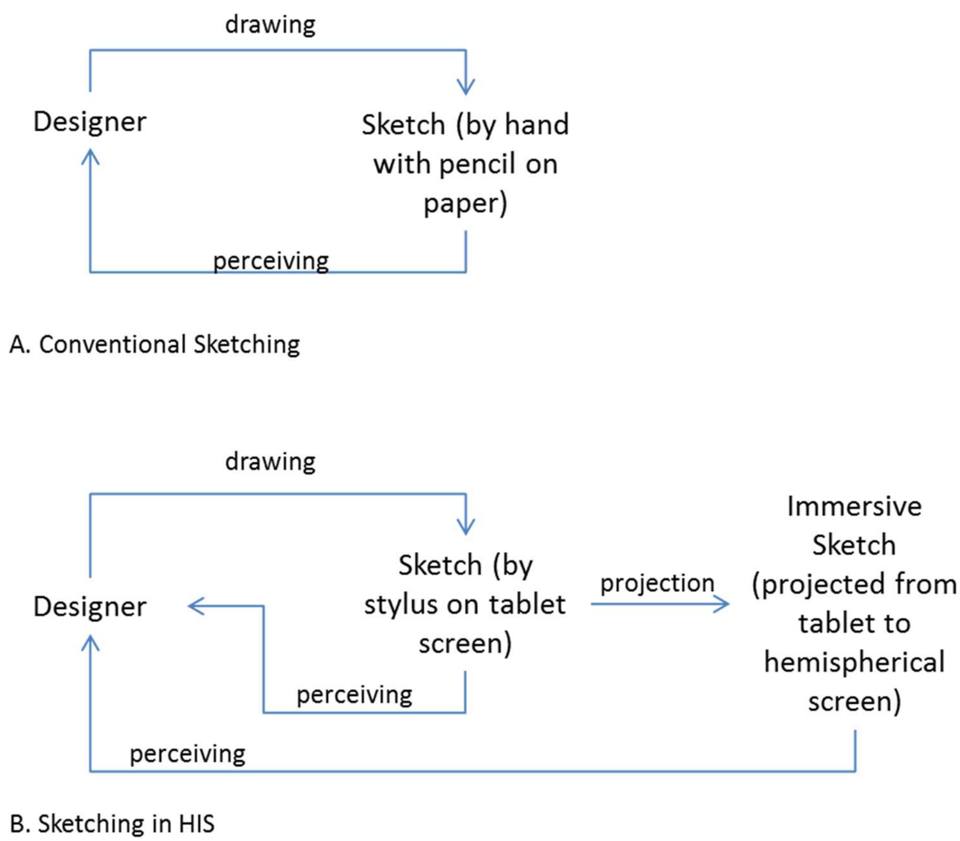


Figure 9 Schematic Comparison of Conventional Sketching and Sketching in HIS

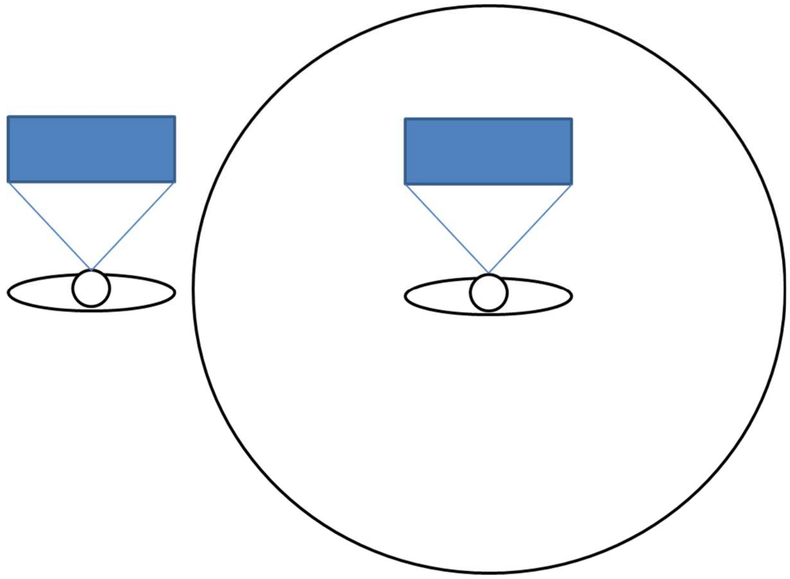


Figure 10: The figure on the left shows the visual surface available in a conventional sketching environment. The figure on the right shows the augmentation of this cone of vision in the HIS

The site used in the background must be prepared as a cylindrical panorama. This can be produced using pictures taken using a normal digital camera. These pictures are 'stitched' into closed cylindrical or spherical panorama using commercially available software.[187] The panoramas should be comprised of at least 8 pictures for good results. Once the panorama has been loaded into the HIS software, it can be calibrated to align the ground and the ceiling of the panorama. As the system is a hemisphere (the southern hemisphere of a globe is analogous), the immersive environment does not provide depictions of ceilings. The HIS must be installed in a room which can be made completed dark apart from the light of the projector so that the projection of the site on the hemispherical screen can be clearly seen.

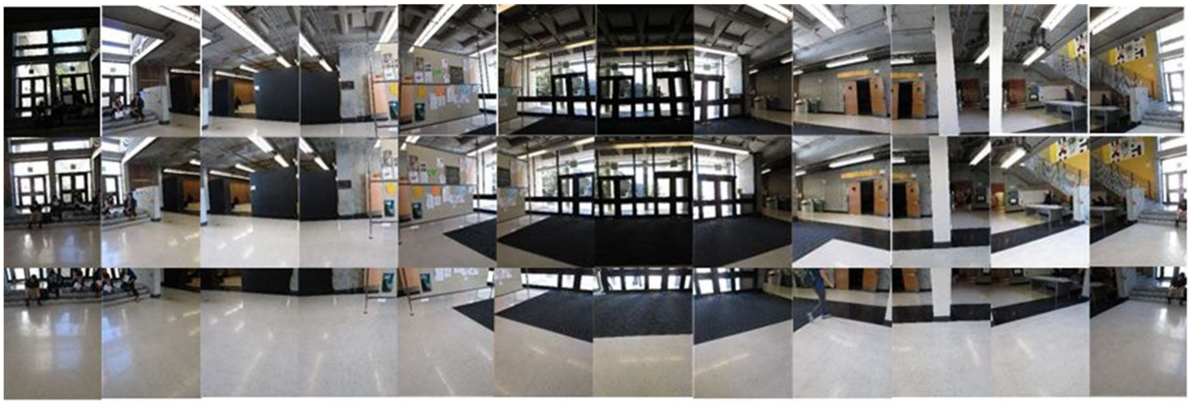
In the preliminary case in HIS, I first entered the space alone and calibrated the panorama of the lobby of Wurster Hall in the HIS system at the University of Montreal. The panoramic image was prepared using 36 pictures taken in the lobby of Wurster Hall. These pictures were then 'stitched' in Photoshop in a two-dimensional array of 12 x 3 pictures. Since HIS is unable to account for the ceiling, the photographs all photos were taken at a height of 5 feet off the ground using a tripod, with the aim of capturing as much of the ground close to the tripod as possible. The generated cylindrical panorama (see figure 8(b) below) was then calibrated in the HIS using further modifications in Photoshop as needed. I arrived at the 12x3 format after attempting numerous other combinations of resolution and array proportions (8x7, 12x2, 9x4 are some of the options tested) to minimize distortion in the stitch and still stay within the specification of HIS. HIS requires the immersive panorama to be no larger than 2000x2000 pixels.

Observation in the HIS is carried out with two video (no audio) IP cameras.[188] One camera is placed in front of the participant; another is attached to the ceiling just above the HIS

[187] Currently, the Photoshop picture editor developed by Adobe Systems, and the Image Composite Editor (ICE) developed by Microsoft Research can be used to develop such panoramas. These tools can also be used to review and adjust the stitched panorama to correct distortions. However, mathematically, some distortion is inevitable.

[188] IP Cameras record and stream a live video feed wirelessly to an assigned server. This arrangement of video is used by Prof. Dorta and his students and colleagues to record sessions. I decided to use the same.

and provides a view down. The two cameras are record synchronously (see figure 9(c)). Sound is also recorded synchronously using a Skype connection. I also installed a backup camera to record video off line to ensure that the participant's work would be recorded in the case of a failure of the wireless internet service.



(a) 36 photographs taken using a tripod

(b) The stitched cylindrical panorama

(c) The panorama being calibrated in the HIS installation at the Hybrid Lab, Montreal, Canada

Figure 11: The process of preparing and calibrating the immersive picture of the lobby of Wurster hall, UC Berkeley

5. Case Studies

Introduction

A set of comparative case studies involving a conceptual design time problem assigned to advanced graduate students at Berkeley and Montreal are described in this chapter. The purpose of these case studies is to demonstrate the complicated nature of mediation, and necessity for the tripartite relationships of the design act described in the previous chapter. Three media are tested, the HIS, sketching at the site itself, and sketching using a set of pictures of the site. Each case is recorded using video, and at the end of each session, the participant is asked to describe their proposal as it stands. The participant is also given breaks every 15-20 minutes to pause and note what they have been doing in the past 15-20 minutes. It was found that participants were exhausted after three (in a few cases, four) such mini-sessions. Transcripts of the design proposal descriptions by participants are given in the appendix attached at the end of this document.

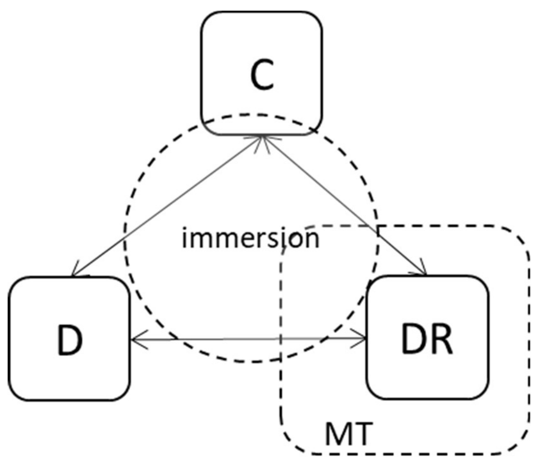


Figure 12: D: Designer, DR: Design Representation, MT: Mediating Technology, C: Context. The mediating technologies are: paper, trace paper, pen and pencil at the site; the Hybrid Ideation Space (HIS); and paper, trace paper, pen and pencil with pictures of the sit

The mediating technologies are: paper, trace paper, pen and pencil at the site; the Hybrid Ideation Space (HIS); and paper, trace paper, pen and pencil with pictures of the site. The mediating technology or representational medium is the apparatus which enables the designer to consider the design problem and develop, modify and examine the solution. The designer's prior knowledge about the site, and assumptions about the site are also involved (C in the above figure).

After an initial set of cases in the three representational media, further case studies were developed at the site and using HIS. The set of pictures are removed as a mode of access to the site and was replaced with a second site – the lobby of Kroeber Hall. This second site was unfamiliar to the participants but had the same problems as the lobby of Wurster Hall and the same design problem could be properly assigned for this site.

The design problem is framed as a short (about 1 hour), time bound, conceptual design problem. Participants are asked to provide a conceptual response to the given design problem. It is not expected that the response be well-formed or complete. The purpose of the case studies is to notice how different representational media frame the designer's attention, what they enable the designer to do, and what they inhibit. The responses are not evaluated for their quality (no claim that one representational medium is 'better' than any other is involved). In a real-world design problem, multiple media would be involved over multiple sessions. Real world design problems are also typically not individual exercises, they involve designing with others (other specialists) and within a broader set of constraints. As a design problem that architects are used to, the assigned problem is not a complex problem. Given the requirement that the designer only produce a conceptual proposal, the problem may even be considered trivial. The purpose of this is to draw attention away from the product, and towards the mechanics of the activity.

The purpose of these case studies is to show the three-way relationship between designer, representational medium and contextual knowledge (or simply, context) is the minimal model of the design act. Further, these cases explore how immersion might be developed as an extensible property of the design act. Previous chapters have shown through theoretical argument why immersion cannot merely be located as a property of the representational medium in architectural design. These case studies serve to exemplify this finding and set the ground for future experimental and developmental work which could examine specific aspects of immersion as a property of the design act.

The three preliminary case studies are described individually in detail. The subsequent case studies are discussed in summary form. Transcripts of the participants recounting of their proposals is provided in the Appendix at the end of this document.

The Design Problem

A single participant was asked to develop a conceptual design solution to a design problem in the first-floor lobby of Wurster Hall, University of California at Berkeley. Wurster Hall is a large concrete building built in 1964 built on the southeast corner of the Berkeley Campus and houses three departments – Architecture, Landscape Architecture and Environmental Planning, and City and Regional Planning. The first-floor lobby functions as a common lobby for all three departments. The lobby consists of a C-shaped stairway leading to the second floor of the building, which hosts the administrative offices of the departments, and is partially of double height. The lobby also serves as the spill out for the café in Wurster Hall, and the largest classroom in the building (112 Wurster). In addition, the lobby also leads to a review space, a gallery, and the smaller elevator lobby which contains two elevators which transport members of the CED community to the studios.

The design brief given to the participant is reproduced in figure 4 above. The participants in this study are advanced, post-professional degree aspirants in the Department of Architecture, UC Berkeley, or professional architects who have just started working in an architectural firm after graduating from an advanced post-professional degree program in architecture. Each participant has substantial studio experience. In each case, the participant was not required to bring any of his own equipment but was given the option of bringing his or her own pen or pencil, should they be in the habit of use a specific model or make for their sketching work. Each participant was provided with a pad of translucent trace paper (9 x 12 inches), a pad of opaque drawing sheets, 2B lead pencils, and red, blue and black pens for drawing. An eraser was also provided. No scale or other equipment normally used for measurement was provided. All sheets provided, translucent and otherwise were not ruled.

A CONCEPTUAL DESIGN PROBLEM FOR A PUBLIC BUILDING LOBBY ON A COLLEGE CAMPUS

Prepare a conceptual design solution for the following situation.

The University today faces many new challenges. The university department buildings have been upgraded in recent years for seismic safety related reasons, but the solutions to the lobby areas of public class room and departmental buildings on campus remain piecemeal and haphazard. For example, in recent years, new technologies for disseminating information to the community, new legal standards for disseminating information about energy and water consumption and new procedures for collecting, classifying and disposing waste, have resulted in the definition of new spaces and objects the main lobby space for many buildings on Campus. Additionally, some of the spaces adjacent to the lobbies have been redesigned for new uses as necessitated by developments in pedagogical, institutional and community needs.

Design the space of the lobby of Wurster Hall to take into account at least the following needs:

Circulation – as a place with numerous entries and exits

Information dissemination

As a place of entrance and exit from the building

As a gathering place at the beginning and end of class

As a place to inform users of the building about the energy use and waste policies that the university is trying to enforce

Your idea could end up as a single installation or as a set of distributed interventions.

Please use the implements provided – a pad of tracing paper, pencils and ink

Total time available – 1 hour

Every 10 – 15 minutes, please take 5 minutes to record what you have been thinking and drawing in the space given below by writing about it. I will prompt you every 15 minutes, but you are welcome to make a record more frequently. You have up to 6 opportunities to make records. I will let you know when you have 15 minutes left. At this time, please collect your ideas in a single sheet using sketches, diagrams, plans, sections, annotations and or other forms which you may find suitable.

Figure 13: The Design Problem given to participants

Participants were asked to propose a conceptual design solution to the lobby of Wurster Hall. Wurster Hall was designed in the late 1950s. Since that period, several legal, technological and social changes have occurred in Berkeley, which have changed the way the students, faculty, administrators and visitors to Wurster Hall use the front lobby of the building. The lobby of Wurster Hall is the common meeting point for the various departments within the college of Environmental Design apart from serving as the main entrance to the building. The entrance to the lobby is from the West and most students and faculty use this entry. Of all the changes that have occurred since the 1950s, three have affected the use of the lobby of Wurster Hall. First, the passage of the Americans with Disabilities Act introduced requirements for specific facilities in lobbies of public buildings. Currently, these, which include a defibrillator and a wheelchair, are placed in a cabinet near the entrance to the large lecture hall. Second, concerns about the environment, consumption of energy and processing waste, have led to new requirements about sharing information about energy consumption and new regimes for collecting and classifying waste. Finally, the invention of the internet and subsequently campus wide electronic information networks has made possible new ways of organizing schedules and sharing information. Currently, this is done in Wurster Hall in a piecemeal manner, through the installation of small computer monitors near the main elevators for instance. Participants were asked to consider if the architectural design of the lobby could be conceptually reimagined to account for these changes, in place of the piecemeal changes being affected currently. Participants were not limited in the extent of the intervention they could propose, either in terms of the extent of change to the current lobby, or in the formal nature of the changes – either as a single intervention, or as a series of small interventions.

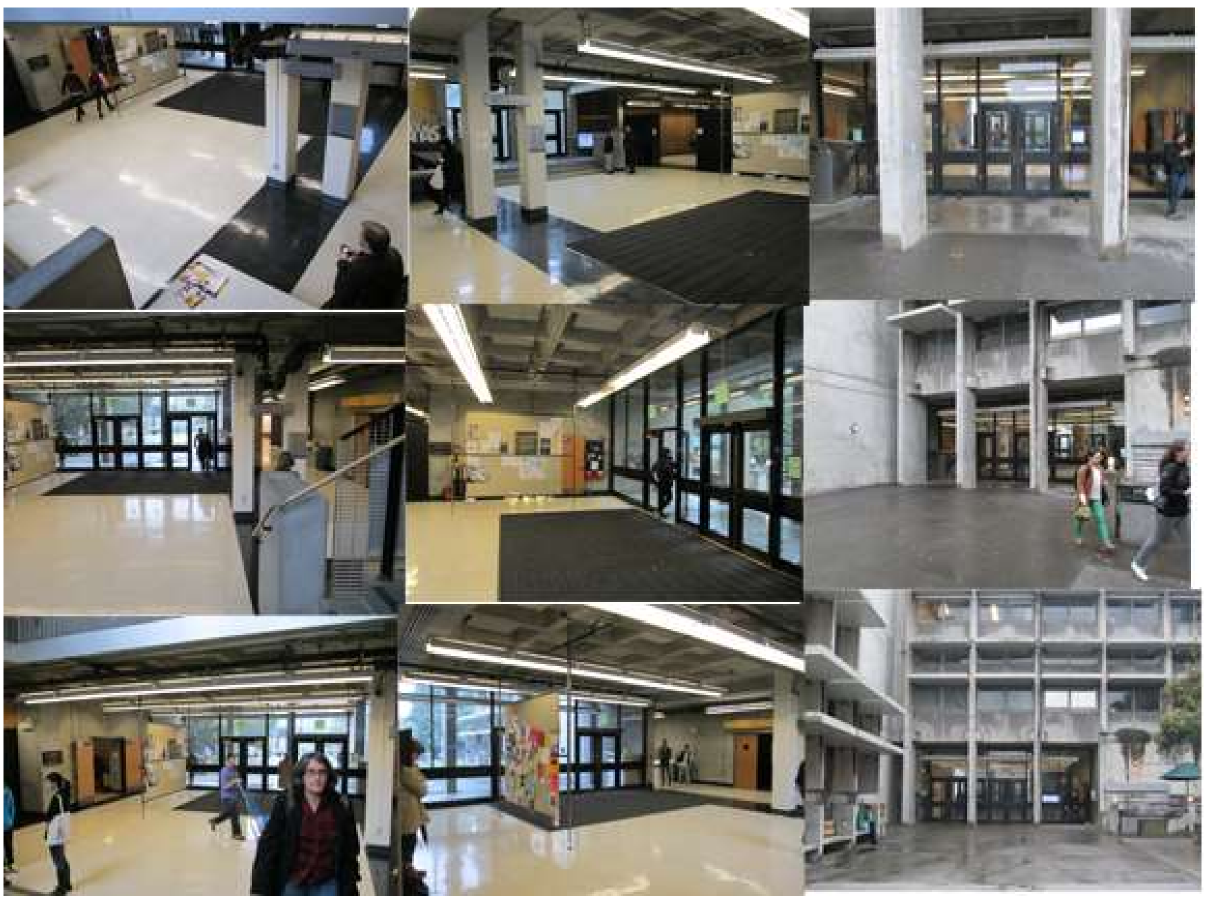


Figure 14: The Set of Pictures provided to participants who used pictures of the site.

This design problem was designed with the view to allowing participants to work in the site and to allow the site to be represented in the Hybrid Ideation Space by means of a closed cylindrical panoramic image. The problem was complex enough to permit multiple approaches and require the designer to consider multiple aspects. At the same time, the lobby as an architectural type is not uncommon. Most large buildings have lobbies which serve similar functions.

Preliminary Case: Working in the HIS

I started by explaining to the participant, H, that the assignment was to prepare a conceptual design for Wurster Hall over a period of approximately one hour. This hour would be divided into intervals of 10-15 minutes, and there would be three to four such intervals depending on the participant's choice. When designing in the site, I could observe the participant at work in person. Due to the constrained space in the HIS, I decided to observe on video most of the time and participate in brief discussions with the participant at intervals. In between intervals, I asked H to note down on a piece of paper (this was provided by me) what he had been doing and/or thinking in the most recent interval. At the end, I asked H to explain the solution that he had come up with, with me. While observing on video, I would make notes. My aim in organizing the study in this way was to maintain as much continuity in the way I observed the process, and the extent to which I participated in a discussion with the participant between the case in the site itself and the case in the HIS.

I started by explaining the context of the site to H while standing in the 'site'. This involved explaining to him what each door and each hallway visible in the site was and what the geographical orientation of the site was. One of the first questions he asked was whether he was standing in the center of the site. "I don't have a plan view, but it's like I'm standing in the center of the site". I responded that he was. The position of the tablet computer is approximately the same as that of the tripod when I took the pictures to make the panorama. I answered all the questions H had about the site, and once this was complete, he began his design work.

H began by looking that the site on the tablet screen, rotating the screen to see different parts of it. He was not very talkative and drew incessantly. He never looked up from the tablet in the initial stages of his work. His work sequence involved drawing on a section of the site on the tablet, and then rotating the tablet to see another section of the site, which he then made further drawings on. He made some observations about the software and asked some basic questions about the site. But conversation with me was significantly less in the preliminary HIS case compared to the preliminary case at the site. Some technical problems with the HIS software also came to the fore, and these were addressed during the preliminary study. One aspect of the software which came to light was the fact that the blackboard afforded a degree of transparency which could make the blackboard feature be used as a vellum (trace paper). This is not an intentional feature of the technology. It is also not noticed as vellum is used differently for industrial design projects such as the design of the interior of a car, then they are for architectural design projects. However, the transparency did not interfere with the primary function of the blackboard, which was to allow the designer to draw away from the site, on a plain surface. I did not get involved in the design decisions, but I did talk to H from time to time when it was time for him to record his thoughts, and whenever he had difficulties with the interface or wanted to offer a peculiarity of the software. Even when he eventually showed me the design he had worked out, H preferred to show his work in the tablet, and never looked up at the immersive screen.

When working in the HIS on this site, the designer is effectively standing in the position of the camera used to produce the panorama. H observed "what I found a bit disconcerting was that since I'm standing in a middle of the room and I can't get a plan view. So, I'm using the blackboard to draw a plan view of my design". When he was working on the designer, I observed that he would zoom out to an extreme degree on the tablet screen to be able to see as much of the 'floor' of the site immediately below where he was standing as possible. H's design scheme involved regulating movement by organizing the space into 4 quadrants normal to the sides of the lobby. He would then make small, focused interventions in the space. H proposed to eliminate the existing notice board since it blocks the entrance to Café Ramona and replace it with a transparent screen hung from the wall, which could provide information digitally, and allow the visual connection between the café and the rest of the lobby to be re-established. Another intervention was in the redesign of the student space below the staircase. H complemented this by creating another student space on the west side of the staircase leading to the 2nd floor. Without specifying the design in too much detail, H's proposal consisted of imposing symmetry of the design along an East-West Axis. The symmetry was further emphasized by the introduction of a pylon. The standpoint located in the middle of the space, a given in the HIS, seemed to be formative in the design. H's method of using the software, by focusing almost exclusively on using the tablet screen also seemed to be play a role.

Preliminary Case: Working at the Site

The participant was invited to the lobby of Wurster Hall and asked to work on a conceptual design for the lobby for a period of approximately 1 hour. The participant was not provided with any drawings or photographs or pictures of the lobby but was asked to design in the site itself.

Figure 15: Participant at work in a preliminary study

I started by handing the one-page document (see figure 8) which introduced the design problem to the participant. The participant is an architect who is at the College of Environmental Design doing an advanced, post-professional degree in architecture. We met in the lobby of Wurster Hall, the building which hosts the College of Environmental Design. The lobby is also the site of the design problem. The participant read the document fully. I provided him with a sketchpad of tracing paper, blue, red and black sign pens, 2B pencils, an eraser, and a sketchpad of papers. No measuring tape or scale was provided. I will refer to the participant in this part of the preliminary study as D for the rest of this chapter.

I recorded what D was doing in the following ways[189]. First, I kept notes, approximately making approximately one note every minute (see figure 3). Second, I performed the role of observer as well as interlocutor, having explained to the participant at the outset that he could use me a sounding board should he feel the need to do so. This included intimating the participant on four separate occasions that he should take a break when he's prepared to do so and prepare a brief record (see figure 4) of what he had been working on during this period. Third, once the participant had concluded the conceptual design to his satisfaction, I conducted a video interview with the participant going over his design work, using his drawings as a prop. I report the results of each mode of recording events below.

D began by reading the brief fully and did most of his work sitting at the location shown in figure 1. He used the trace paper, pencil and colored pens that were provided. To start, he measured out the site using steps, and made notes on tracing paper. He developed this further and drew a grid on the trace paper. While doing so, he mentioned to me that perhaps it would have been useful if I had provided him with pre-drawn square grid to work on. No measuring instruments or gridded paper was provided. All trace and drawing sheets provided are plain. Based on this grid, D proceeded to create produce a floor plan. He made frequent use of the eraser while doing this and used the same single sheet of trace paper with which he had begun to develop the grid and then the floor plan. While doing so, on three occasions he revisited measurements he had earlier taken (his "unit" was the length of his stride). On one of these occasions he used his stride to measure the length from a wall to the main entrance to 112 Wurster Hall. By the time D was completing his measurements and drawing up his floor plan, it was time for the first break as per my time clock. I indicated this to D by telling him that whenever he was ready, he should take a break and record what he had been thinking about. In his response at the time, D reported that he had "assessed basic dimensions", "called to memory various scenarios of use", "highlighted, considered, and assessed people densities and movement" and had begun to assemble his idea.

After completing this brief note, as he was returning to his work desk, D observed "this stupid table is always here, and they'll never move it". He continued his work by using a new trace paper and setting it up by placing it above the floor plan he had previously made. He then stepped away from the work desk and went outside through the front door of the lobby to look at something through the entrance to the lobby. This examination continued for nearly 4 minutes. During this time D walked around the entrance to the building and then around to the entrance of Café Ramona's behind the existing notice board. He then walked back out of the building through the entrance and walked a small distance away from the entrance. He turned around and observed the entrance to the building from this distance. He then walked back through the entrance. I moved away from the desk to observe him but did not follow him very closely. I

[189] For a detailed discussion of the experimental method please refer to Chapter 3 of this dissertation.

stayed inside the lobby through this time. When D returned, he observed that "The thing is that there is no reception. But then I wonder whether a reception is necessary". He continued by talking about the history of the building, and specifically to the idea that Wurster intended the building "to be exposed". D wondered if the "the lobby of the building should be in dialogue with this idea, or whether it should be in opposition to it" He then walked back to the entrance and asked me "can this thing go away". I replied that it could be as he (the designer) wants.

By now it was time, according to the clock, for a second round of observations. I reported to D that whenever he was ready, he should take a moment to write a second set of points about what he had been thinking of under "Two" in the sheet given to him. Just before he began to note down his second set report of what he had been doing, he pointed to the notice board and the tv screen in the corner near the staircase and said, "All this can be digital". He reported the following points in the sheet. "Begins to assess situation scenario", "question technology", "question conceptual standing of Wurster", "question points of assembly", "multiple points; Part of the narrative", "information – Wurster exposes information of the building scheme". After completing his second entry, he said "Ok, so I have my idea".

When he returned to his design, D briefly left the desk and walked around. A couple of his friends from studio walked by and said hello to him. They asked him what he was doing. He told them that he was designing the lobby of Wurster Hall for me. He returns to the tracing and thinks aloud about this idea. "Without all this glass it would be dark in here". But then, after a while walks this observation back "Well, not really". He is referring to the high glazing in the double height above the rear door of the lobby. He is drawing on a new tracing placed above the base floor plan, which he seems to repeat on the new tracing in outline. He draws for a while. Then, after drawing in silence for some time, he observes "I can't draw as fast as I can think". He turns around to the staircase and notices the large blank wall next to the flight, which is covered by the mural. He talks about the possibility of "a skylight along the flight of the staircase in place of the painting", but then realizes that "the library is behind that wall". He turned his attention back to the entrance and worked on his tracing for the next few minutes. He observed that he could "extend the slab outside to increase the size of the lobby". A couple of more friends walk by and he stops to talk to them. They ask what he is doing in the lobby, and he tells them. He continues to work and thinks aloud about the problem of "library access" and "book drops".

D continues to work on his tracings and it is time to make his third set of observations. This time he continues to work for a few minutes after I indicate to him that it is time. While doing so, he observes that "everyone walking in and out of the lobby uses only one of the two doors. No one uses the door nearer to Ramona's". He analyzes why this is, and his idea is that this is perhaps because the door to the right is precisely that – off to the right, and not in the path of most people who access Wurster Hall. He finally stops to observe under "Three" – "assessment of critical points of flow and collection", "over more than one day – weekday/weekend", "people use the same door to enter". As he writes this down, he observes that he has been a little distracted during these past few minutes because of friends stopping by to talk to him. I point out that this is largely unavoidable given the fact that we are in the lobby of Wurster Hall.

D resumes work on the design, using a new trace paper. This time, he uses the blue and red pens to draw. As he draws, again using the base plan as a tracing paper and drawing some of this plan on the new sheet, he says to me "I have a fair idea of the design now" and wants a few more minutes to draw. As he makes this drawing, he observes for a second time that "having graph paper would have been useful". He is now drawing and thinking aloud intently. I let him draw without interfering or asking questions, given that when he is done, he will take me through his ideas and drawings while I record the same on video. I recorded D's explanation of his work. It took 8 minutes and 18 seconds. D's sketches can be seen in figures 5-10.

The participant's report of his work after finishing it: I asked D to take me through his work in the order in which he prepared the sheets. When he prepared the sheets, I had asked him to number them. As he explained what he had done, I also asked him to overlay the correct combinations of sheets as he had originally used them. What follows is a summary of what he described. A video record of this report by D is maintained.

D began by measuring and drawing a plan of the lobby "just to see what it looked like". He then began to imagine how people moved through the space and how they were collected in it. He called these two aspects "critical flows" and "critical collections" respectively (see figure 6). Here, he mentioned that since he passed through the lobby "a lot", he had a good sense of how people moved through the space and where they collected. He said that since he was not going to be in the lobby for "hours" he couldn't do a systematic study of how people moved and how they collected, but that he had to rely on his understanding of how the space was used – an understanding built from his own frequent use of the space as a student in Wurster Hall. He observed that "people get lost when they come in here. When I first came here, I did not know where anything was, because there is no information available down here". I asked him about the drawing he made in figure 6, and he remarked that his drawing was not strictly accurate. Later on during his work he had observed that most people were using the door on the left (as one enters Wurster Hall), while the door on the right was rarely used. The drawing was intended to stand in for the idea that the major flow was from that front entrance to the large classroom and the smaller lobby containing the elevators.

D's conceptual design consisted of 4 specific interventions. First, he proposed to "get rid of" the existing noticeboard (which currently faces the entrance to Ramona's) and to use the blank wall next to the entrance to Ramona's and the two columns near the large stairway as spaces for digital displays of notices and basic information about the building. Second, he would extend the grid of the exposed roof slab outwards, pushing the western entrance to Wurster Hall further outwards and have a steel grid dropping down in the higher ceilinged space just outside the present entrance. Third, he would also shift the entrance to the building to the right, closer to Ramona's, thereby effectively splitting the lobby along his basic "critical collections". This would help organize and separate, according to D, the collection space outside the classroom, and the pedestrian traffic in and out of the building. Fourth, he would build a reception desk in front of the two columns (which would bear a wrapped digital information display), and remove the large desk near the staircase on which he was currently working on this design.

Preliminary Case: Working using Pictures

In Case B, the participant was provided with a set of 10 photographs of the Lobby of Wurster Hall. This set was unbound, and each photograph was printed full size on a Letter sized page. The photographs were initially provided in a sequence which simulated a walk through the lobby starting on the staircase leading down into the lobby and ending in outside the western entrance to the lobby and building. The pictures were taken so that they could also be arranged to simulate a walk through in the other direction as well. The pictures are provided in Appendix A of this dissertation. As he drew, S observed that the lobby should provide the opportunity for accidental interactions, but that Wurster's lobby does not since it is so over loaded with functions, with so many important spaces in the building being directly connected to it.

Figure 16: Participant at work using pictures.

I provided the participants with the set of 10 photographs stacked in sequence. The participant spent the first 10 minutes looking through the pictures and the given brief (figure 4). The participant, S, then made his first note. *"The current lobby can't just be a spillover space for Ramona's and 112. It's not sized for anything else but that, and with all the cluttering in that space, it's a space you want to leave as soon as possible rather than linger, look around and notice things like the tables near the stairs, the exhibition space next to Ramona's etc."* After writing this first set of observations, S made a section through the building first, and then planned to record the "current situation".

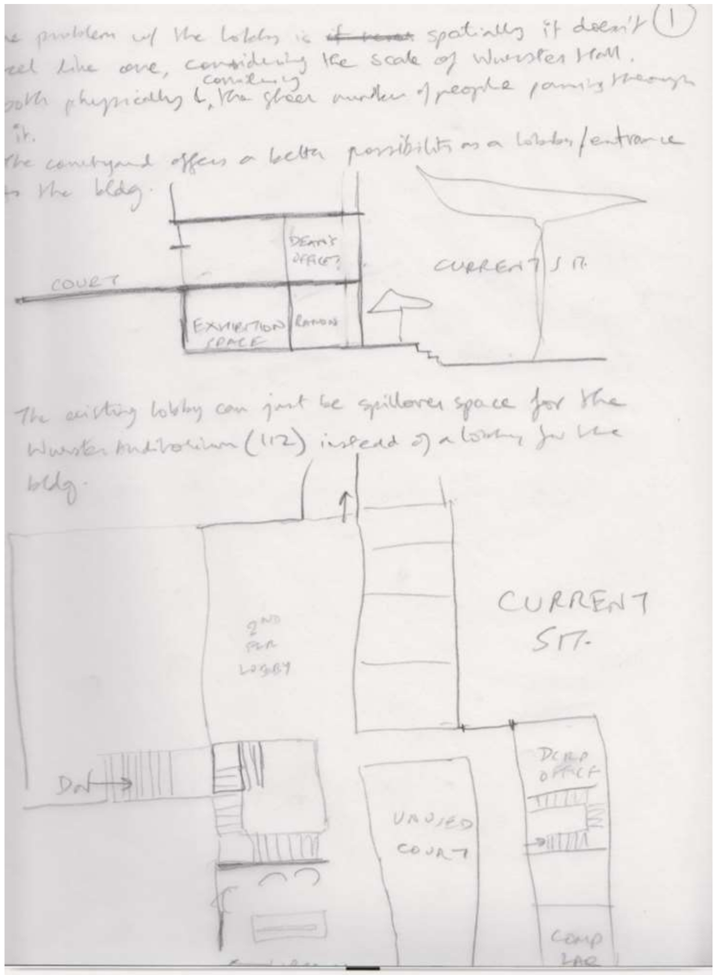


Figure 17: First figure drawn by participant. He began by drawing a section through the lobby space.

Once S began to draw, starting with the section and the plan, he set the pictures aside in a neat stack and only occasionally referred to the pictures. One important aspect of S as a participant is that he was familiar with the lobby as a regular user of Wurster Hall. However, he observed, when I first provided him with the problem, that he had not noticed the many new uses that the lobby had been put to, especially the information about energy use, waste disposal, and the disability act related material, and that when he walked through the lobby he was typically in a hurry to get somewhere and didn't normally stop and think about how to use it. On the brief, S observed that initially it read like a "straightforward design problem" which asks, "what do you do to a lobby which is clearly under-designed for the number of things that are happening in it or are supposed to happen in it". One of S's "pet peeves" about the building is that "it does not take advantage of the courtyard at the back and the second-floor lobby space which spatially at least provides the opportunity to let you do a lot more". This drove S's "first impulse" to start with the section, and then focus on the second floor of Wurster Hall to start with.[190]

After completing the initial drawing of the current situation, S used a fresh tracing paper to trace over his plan of the current situation to outline the 2nd floor above the lobby. His proposal involved extending the double height on the 2nd floor into the existing study area near

[190] Quoted portions are things Sidharth reported to me

the Dean's office and defining the second floor as a lobby rather than as an entry which immediately leads to a study space. The existing lobby on the ground floor would remain the same, but with the new focus on the second level, S sought to invert the relationship between the current entrance on the 1st floor of Wurster Hall, and the current secondary entrance from the courtyard on the 2nd floor. The design of the building, according to S, allows the lobby to be "flipped depending on requirements over the next few years". The primary entrance to the building could alternate between being on the 2nd floor and on the 1st floor, if the entrance on the 2nd floor was defined more as a lobby, and less as a study area. As he said, "There needs to be awareness that there is a two-sidedness to this building, that can be taken advantage of". Towards this, after imagining the entrances to the building being flipped, S proposed extending the raised platform outside Ramona's to become an extended "backyard" to the building, which would serve as a spill out for the auditorium (112 Wurster) and serve as a place where students can eat their food.

What began as a conventional design problem involving a set of requirements became a problem of conceptualizing the lobby space itself. This occurred because three initial insights. First, that the existing space of the lobby was not large enough to accommodate the many functions necessary. Second, that the rear entrance to the lobby, which opens on the 2nd floor and on the 1st floor was not currently utilized as well as it might have been. Third, that what was necessary, in S's words, was to "recognize that the building permits flexibility in meeting requirements" as they emerged due to changes in the technology and laws. The conceptual solution thus became one which enhanced the current lobby's capacity of being flexible.

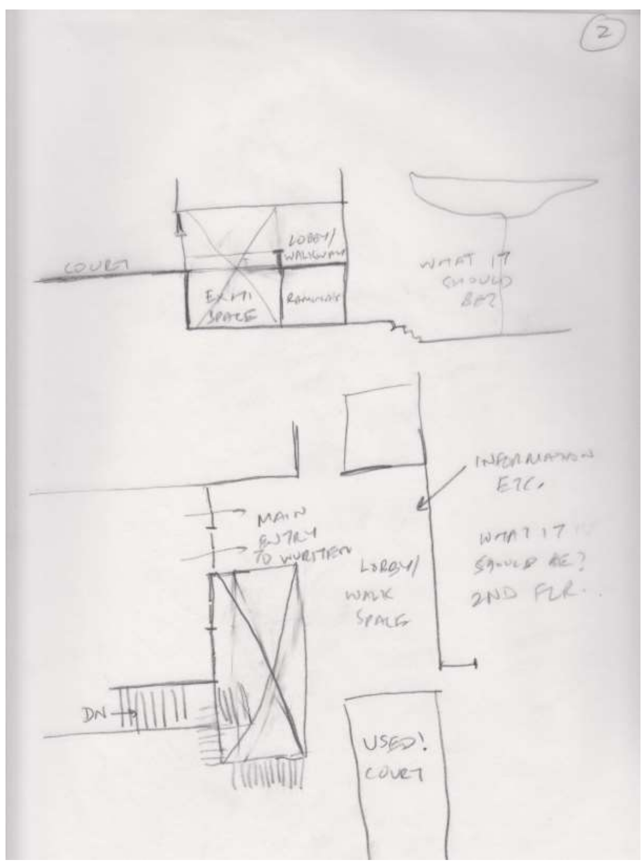


Figure 18: S's second sketch showing a plan of the 2nd level with the proposed expanded double height space

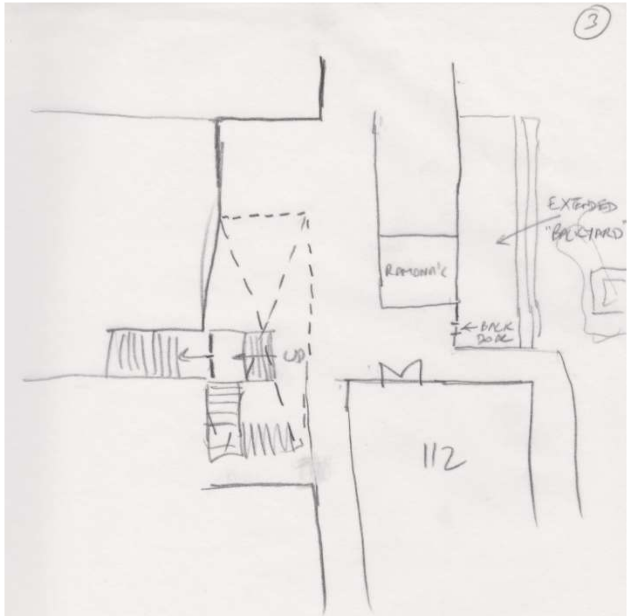


Figure 19: S's final sketch showing a proposed plan of the 1st floor, with the extended "backyard"

Preliminary Discussion

Three representational media are considered in the preliminary cases: paper, trace paper, pen and pencil at the site; the Hybrid Ideation Space (HIS); and paper, trace paper, pen and pencil with pictures of the site. No plans, sections or other measured drawings of the site are provided. As stipulated by the model of the design act, if we consider the relationship between designer and representation (which is accessible within a representational medium), there are three basic activities involved with designed (there are others, but these can be organized within these three broad categories). First, designers can make marks – write or draw or use some other abstract symbol system – about the design proposal. These may include spatial drawings of ideas, written information, calculations etc. Second, designers can observe the representation. As discussed in previous chapters, representations are abstractions and aid cognitive activity. Third, since this is an architectural design problem and the human scale is a central fact, designers can reposition themselves in relation to the representation of the problem or the site. This can involve scaling, rotating, panning, or changing the abstraction (or switching between representations). Each representational medium affords this in distinct fashion. The table below describes each of these capabilities for the three representational media used in the preliminary cases.

Representational Mode	Mark making capabilities	Observational capabilities	Repositioning capabilities
Working at the site	Pencil or ink on plain, unruled paper. Tracing paper to trace over previous work. Erase, modify and add to marks with pencil or ink.	Observe the drawing or representation produced on paper, switch between looking at the site and looking at the paper	Walk in the site, observe the site at real human scale from any position on the ground at the site. Repositioning occurs in real time, so it is possible to observe changes at the site as well.

Working in HIS	Stylus on tablet. Stylus can adopt varying mark thicknesses and colors. Marks can be made on a picture of the site, tracing features available in the picture. Blackboard – a screen which can be invoked in the immersive environment. This is intended to allow the designer to sketch in a place other than the site. However, the blackboard is translucent and can serve as partial vellum on the site if required.	360-degree access to the site. The designer has a sense of which part of the site is behind, to the left, to the right, in front, above and below. The cylindrical panorama is calibrated to the human scale. Observation is possible from the center looking outwards. Observation is also available on the tablet screen itself where it is possible to focus on a section of cylindrical projection of the site.	The designer can turn clockwise or counter-clockwise in 360 degrees while maintaining bodily relationship to the site. It is also possible to move a small distance radially from the center (since the designer is positioned in the center). However, the designer's position at the center of the site is fixed. No other standpoint is available.
Working with pictures	Pencil or ink on plain, unruled paper. Tracing paper to trace over previous work. Erase, modify and add to marks with pencil or ink. The vellum can also be used to trace over any of the pictures of the site.	Pictures can be viewed individually, in combination (i.e., multiple pictures side by side), or in sequence.	The available are limited to the points of view from which the pictures are taken (as given in Figure 14**Error! Reference source not found.**). No other viewpoints are available.

Representational media enable mark making on some material media. More generally, a representational medium enables mark making in some abstract space. The three representational media were devised with the intention of modifying specific features of the medium in each case. The pictures provide an opportunity for tracing over a perspectival picture of the site, as well as drawing on plain paper as needed. HIS enables tracing over a perspectival picture of the site in an immersive setting in which the designer's location is coincident with a location in the representation such that the designer feels that she is in the design site. Plain paper is not provided in the HIS, but the blackboard could serve this purpose if needed. At the site, the designer is actually immersed in the site (in the conventional sense), but mark making is only possible on plain paper or vellum, and not on any perspectival picture of the site. Observational affordances are similarly varied. In the site, the designer can move and observe whatever she wants from wherever she wants. With the pictures, a fixed set of views from a fixed set of standpoints are available. In HIS, the designer can turn a full circle from one fixed standpoint at the center of the site and observe the full site from this solitary position. Further, being at the site meant that the site could be observed over the course of an hour. The other two representational media provided a static snapshot of the site at exactly one moment in time.

The participants involved in the preliminary studies were all equally advanced but did not know the site equally well. H (in HIS) did not know the site at all, while D (at the site) and S (using pictures) knew the site well. This influenced how the participants used the representational media. Knowing about the site means not only knowing spatial facts about the site, it also means knowing facts and having experiences about the use of the site which are not available to those who don't know about the site. For example, D observed that "[w]hen I first came here, I did not know where anything was, because there is no information available down here". This influenced D's understanding of the nature of the lobby as key point of access to the rest of the building. This is not merely additional information about the site, it shapes, to use Dreyfus's term, the designer's disposition towards the site.

All the participants in the study were conventionally trained and so had achieved facility for using standard abstractions like plans and sections. In HIS, H used the blackboard facility to make a plan of the site. H also used the zoom facility in the HIS to zoom out to the maximum possible extent to be able to "see" as much of the floor as possible to do this. H felt discomfort in not being able to make a plan with the usual ease. S and D did not encounter such discomfort. HIS provides one mark making surface but two viewing surfaces – the tablet and the projection (see **Error! Reference source not found.**). H's early inclination was to draw on the tablet and keep working on the tablet and use the projected picture only infrequently. H reported that "because the image on the tablet is so much sharper, I'm instinctively working on the tablet. Instead I could do something like this [looks up at the projection and draws on the tablet screen] It is harder to do this than to look at the tablet than to draw on the tablet."

Even though the participants were equally advanced practitioners of design, and equally proficient at sketching, the HIS as a representational technology still presented teething problems which were not evident in the use of pictures or work at the site itself. This suggests that sketching in the HIS is a distinct skill from mere sketching. This skill involves developing different representational expectations and learning to think in three dimensions differently from approaches which involve quick abstraction between two and three-dimensional views of the same model.

The preliminary case studies show that skill and familiarity are significant aspects of the design act as far as its cognitive economy is concerned. In this case, the skill is concerned with having to adjust to the constraints of a different sketching system. Familiarity permits users to involve considerations beyond those which are indicated merely through a reading of the representation (as it is available in a given representational technology). Each can be considered an aspect of immersion in the design act. In each case, the immersion in the design act is related to the narrower geometrical immersion in the design representation.

To examine the idea of familiarity, a second site – Kroeber Hall – was introduced. A comparison of designing in the site at Wurster Hall and Kroeber Hall is considered. The rest of this chapter focuses on designing at the site and designing in HIS. The case studies involving pictures are not used in the current discussion.

Designing at the Site

Designing at the site involves observing the site itself and developing a design on paper while at the site. Participants adopted two distinct approaches. The first approach involved a high degree of observation and reflection about the site. The site is not available as a snapshot but is available in real time. Things occur at the site while the designer is working there. Conditions change. For example, a class finishes, and students file out, or a visitor comes into the building and looks lost. These experiences are uniquely available to designers at the site. The second involved a high reliance on the design program (see **Error! Reference source not found.**). This programmatic approach involved referring to the site periodically, but mainly attempting to address the different aspects of the program, rather than develop a single broad conceptual response.

As discussed in the preliminary case, D (WS1) professed familiarity with the site and proposed an organizational scheme which effectively split the lobby in half, a northern half intended for 'collections' and a southern half intended for 'flows'. This was based on a broad idea of thinking in terms of flows and collections. While this conceptual, spatial arrangement drew on the participant's familiarity with the peculiarities of the lobby, the formal response drew on details of the lobby, such as the location of the double columns and the fact that the space between the two columns is not sufficient for a person to pass through, the double-ribbed exposed ceiling, and the full glazed doors. WS1's work approach relied of constantly redrawing the site with small additions. But it also relied on reflecting on observations. For instance, the reflection about the consequence of removing the glazing above the glass doors, combined with the reflection that at the West entrance, the northern door was used far more frequently than the southern door led to the idea that the entrance could be halved. The site served as a device for focusing memory, since the point about the door usage could not have been evident from the hour of observation but was deployed from accumulated past experience. WS1 worked seated at the table near the staircase, but occasionally left his place to examine specific aspects of the site.

WS2 was also familiar with the site. WS2's approach was not programmatic. Her first observations were that the site satisfied most of the requirements in the brief, and so it would be best to preserve as much of the existing facility. WS2's intervention emerged as an installation which would inform while existing as an addition or modification to the lobby, rather than as a programmatic overhaul. This installation (which is in two parts) developed from the double-height of the staircase and was localized in this, the north-east corner of the site. The first part took the form of a foldable screen which would hang down from the railing of the landing above, fold down over the ceiling and drop down where the double-columns are. From here it would extend on the floor in the form of screen tiles. WS2's idea is to develop this screen tile installation as a responsive, informative device which would function without interfering with the existing facilities and, natural light and sight lines. The second part of the installation involved constructing a back-lit chute breaking the first-floor slab in the north eastern corner of the site. WS1 spent 37% of her time observing the site, and 63% of her time drawing or writing. Much of the observation was done standing in the lower landing of the staircase with attention to the north-east corner of the site.

WS3 used his familiarity with the site to focus on the design problem. This participant spent nearly all his time sitting at the desk in the north-east corner of the site. Only 4% of his time was spent looking into the site and observing it. WS3's approach involved identifying the circulation pattern in the lobby by first locating all the entry and exit points, and then using this information to locate the areas where the circulation paths cross each other. The double-column came into focus as an important aspect of the site here, since it influences the circulation patterns in the lobby. WS3's approach was minimalist, and he preferred to add to the site rather than modify it. The proposal emerged out of the study of circulation patterns in plan in the form of a distributed installation which would physically serve to reinforce these circulation patterns while accommodating the requirements from the design problem.

KS1 worked on the lobby of Kroeber Hall, a site she was not previously familiar with. The design problem and the program in it provided a guide for the participant to get to know the site. Art Practice and Anthropology departments at Berkeley are located in Kroeber Hall. Student art work is displayed in the lobby (paintings on the wall, video and installations in glass cases along the wall). Two classrooms have entrances into the lobby. An enclosed staircase is located to the north side of the entrance to the lobby. Through an initial examination of the site with the lens of the design program, KS1 concluded that the energy displays, and waste management issues were most obvious shortcomings. KS1 then began to draw the plan while observing the site. This process brought to light two other problems related to circulation. The entrance to the large class room was hidden away behind a set of columns, and the enclosed staircase was occupied by students gathered between classes, while the lobby itself was not a gathering space. These insights were localized. Seeing students gathered in the staircase area and seeing the large number of students leaving the classroom (an observation which indicated the unexpectedly large size of the classroom) were events which could be considered idiosyncratic to the time of observation. They became significant to KS1's understanding of the design problem because they occurred while she was working on the problem. KS1's proposal (**Error! Reference source not found.**) involved opening up and reorienting the staircase block and improving the definition of the spill-out area of the class rooms and the circulation area. KS1 made the decision to locate information about the energy and water consumption near the elevator, reasoning that people might look at it while waiting for the elevator. The waiting or spill-out space is demarcated from the circulation space with an installation which can host artwork. The lobby was busy when KS1 was working on the design problem and this influenced the development of KS1's conceptual proposal.

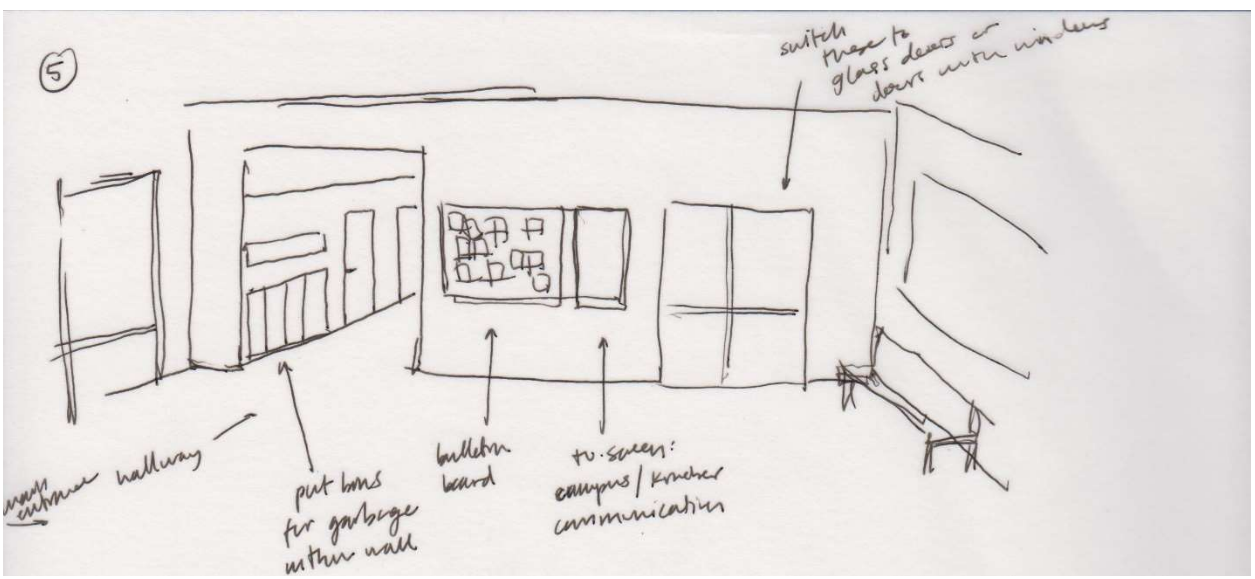


Figure 20: Proposals for the South Wall, perspective sketch, KS2

KS2 was unfamiliar with the site at the start, and initially conducted a form of reconnaissance to determine what all the doors and hallways led to. KS2 worked on the site during a quiet period of the day. The governing feature of KS2's approach was her interest in the south wall of the lobby. This wall has entrances to classrooms, the opening of a long hallway which leads to an art gallery. KS2 also made the observation that the art display cases (which are large glass boxes with wooden frames) gave the lobby a "blockiness". KS2 described her proposals using annotated perspective sketches (**Error! Reference source not found.**, Figure 34). The proposal was less intrusive than KS1's case, and mainly involved reordering and updating existing installations and facilities within the lobby rather than any fundamental restructuring.

The case studies of designing at the site described above can be organized into two classes. At the outset, it is evident that the design proposal develops through a three-way interplay between the design program, the site, and the representation of the design proposal. In the current representational medium, the design proposal is represented with sketches made in pencil or ink on plain paper or vellum. The site is the site itself, and the design program is as discussed at the beginning of this chapter. Different parts of this three-way relationship are generative for the development of design. All five design proposals cannot be said to be equally complete, even equally well-formed or even equally successful. This is common with time bound problems. The success of the proposal is not a significant concern. The mechanics by which the proposal comes about is the central concern. In all cases, the drawings prepared by the participants during the development of the proposal took the form of the standard plans, sections and elevations. These were sketched and not prepared to scale, but the standard designer's concern for proportionality was evident.

From this standpoint, it is evident that in the case of WS1, WS3 and KS1, it was the drawings which were generative. In the case of WS2 and KS2, it was the site which was generative. In all cases, the program served as a guide for what was required. WS1 proceeded through repeated re-drawings of the plan in which concerns based on his familiarity with the site and observations of details at the site were incorporated. WS3 developed his response based on a study of circulation patterns developed on the floor plan. KS1's proposal developed along similar lines to that of WS1, with a concern for organizing the gathering spaces and circulation spaces so they don't get in each other's way. The site was not familiar to KS1, and events at the site during the design session shaped the proposal. For WS2, the imperative to retain the existing lobby and the view that most of the requirements in the program were being met already created the opportunity to develop an art installation whose design was shaped by observation of the site. WS2's conceptual proposal did not involve significant drawing work, but instead involved a written description alongside annotated diagrams. A section through the site contributed towards the proposal, but it was the experience of the site, in large part from the lower landing of the staircase, which proved generative.

These two generative modes can be understood as two distinct modes of immersion evident in design acts using this representational medium (pencil, ink, plain paper and vellum, at the site). These case studies have shown that at least these two modes are evident in the most basic design act (involving an individual designer). One feature of this representational medium is the clear separation between the mark making apparatus (pen, pencil, plain paper and vellum) and the representation of the site (the site itself for an hour). In the case studies involving HIS, this decoupling is not as clear.

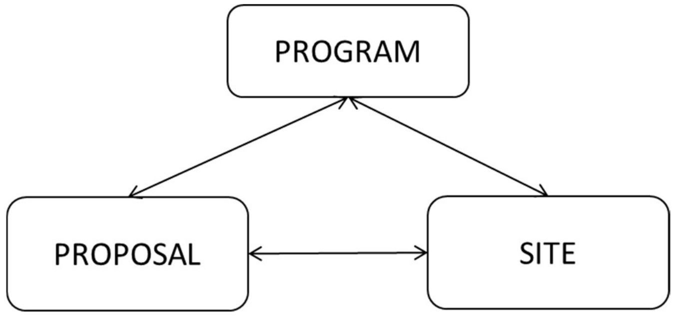


Figure 21: Three-way relationship in the case studies at the site

Designing in HIS

The proposals developed in the HIS had two distinct sets of features. While distinct in their specific proposals, all four proposals saw the visual appearance and lack of definition in the lobby as a shortcoming. Access to the site in the HIS is characterized by a radial view of it from the center. It was not possible for the designer to move away from the central position. This is a strict limitation of the technology. The four participants were not familiar with the site.

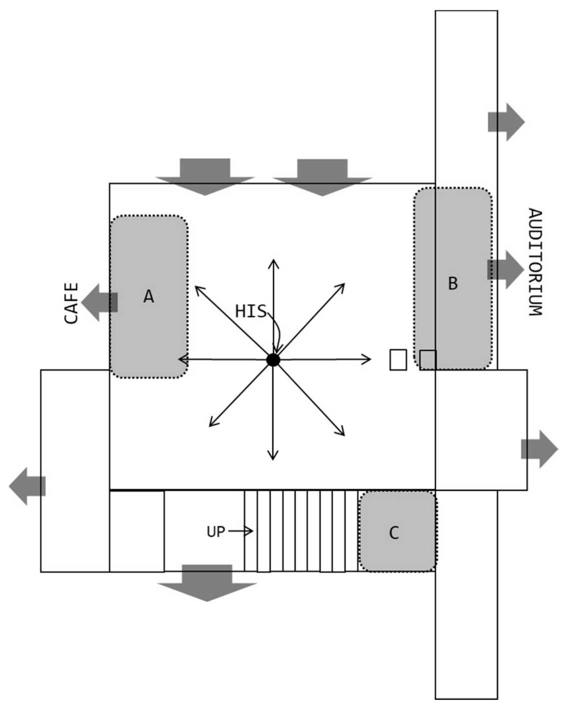


Figure 22: A, B and C are three areas of attention common to proposals by WH1, WH2 and WH3. The location of HIS is shown.

WH3 observed that the lobby seemed to be plain and nondescript for the main lobby of the architecture and planning building. WH2 observed that the space needed to be less austere. WH1's proposals aimed at adding definition to parts of the lobby, creating spill outs for the café and the auditorium, and updating the space below the staircase into a student breakout area. A central concern in their proposals was the visual aspect of the site. The definition of the site was also a concern for WH4. WH4 proposed the use of drop-ceilings (false ceilings) to give definition to specific areas within the site. WH4 also proposed a central spine which would emphasize the symmetry of the lobby with a void in the 'center' (the 'center' refers to the designer's standpoint in the HIS). This central spine would accommodate requirements for various types of information necessary in the lobby.

All four designers worked mainly using the tablet computer. This is the screen on which the designer can draw. The drawing is projected in real time on the surround hemispherical screen. But to observe the screen, the designer has to look up, and then look down again to draw. The time spent drawing and observing the immersive projection by the four participants in HIS is as shown in the table below. WH2 worked on her design sitting on a chair.

Case	Time spent drawing	Time spent looking at the site	% Site time
WH1	1730	300	14.8%
WH2	1560	0	0.0%
WH3	2490	240	9.6%
WH4	1880	120	6.4%

All four designers found the interface relatively easy to adapt to and used the rotational ability of the HIS and the facility for rotating the projected image regularly. In all four cases the designer's initial study of the site was conducted using the tablet screen as the primary visual interface, and only occasionally did the designer look up at the immersive projection. The four designers used HIS essentially as a continuous sequence of pictures which can be imagined as elements which would make up a 360-degree panorama.

While the participants used the tablet screen exclusively while designing, when explaining their work after the fact, they did not use the tablet screen, but used the immersive projection as their visual aid. As the scholarship on the HIS confirms, HIS has been used effectively as a (local and remote) collaborative design environment. Its use as an immersive sketching environment for a solo designer suggests that the tablet screen, being the drawing screen, also serves as a convenient visualization screen.

The four case studies of designing in HIS show the lack of familiarity with the site, coupled with a restriction on movement within the site have shaped the intervention opportunities for the participants. The most common interventions occurred at A, B and C (**Error! Reference source not found.Error! Reference source not found.**). Being unfamiliar with the site and having had no prior experience of using the site, the four participants were faced with a high-resolution visual picture from one standpoint to work with. This can be considered a restrictive mode of immersion for the individual designer.

The participants who worked at the site were able to design for a longer period of time than the participants in HIS. As WH1 observed "Not being able to see the plan view and the section view, and so, not being able to see how this space connects to neighboring spaces felt like a constraint. And I also don't have a site plan, and now I'm beginning to feel this constraint, so that's where I decided to stop. I don't have an idea right now but may be another day I could erase some of this and work on a new scheme. But it has been quite a fluent process. I didn't get bored, I didn't get frustrated by the UI. The time seemed to pass very quickly. From here, if I wanted to communicate something, maybe I'd start color coding. This is like a napkin sketch. Once you have this, and then someone gives you a plan of the whole building, then I would move to a different media."

The reference to the "napkin sketch" in WH1's comments does not refer only to level of detail of the sketch. Rather, as the first part of that quote suggests, it refers to the limited set of facts about the site which form the basis of the sketch. While designing at the site required participants to work with pencil or ink on plain paper, their ability to move around at the site and explore it from different standpoints was not inhibited. The familiarity of some of the participants in some cases helped, but as the cases from Kroeber Hall show, spatial familiarity, especially for a site of the complexity of the lobby of a college building, is easily acquired during the course of an hour-long time problem. Temporal familiarity – accumulated knowledge about events which occur at the site at other times - is harder to acquire. In the case of the HIS, the context available to participants unfamiliar with the site was limited to what they could see of the site while standing at one point in it.

Concluding Discussion

The current state of the art of the theory of the design process is that to the extent that design can be described systematically, it is a technologically enabled practice whose purpose is to convert existing situations into preferred situations. This state is the result of a specific history of attempts to theorize design as a systematic process based on assumptions about the (computational) nature of human cognition. In the first part these have been discussed anew with an emphasis on the nature of design as an action rather than as a type of knowledge. The ubiquitous use of computers in contemporary architectural practice and the nature of the computer as a meta-machine (a machine which describes other machines) suggest that technological advancements in computer aided design have occurred (and will continue to occur) at a rapid pace. These developments make a systematic model of the design act an urgent necessity. The minimum requirements for the simplest such model have been developed.

The simplest design act consists of a one designer working on a design problem which is accessed through some representational medium and about which the designer may know facts outside the data explicated in the representational medium. The representational medium enables the designer to modify the design representation and learn or create new knowledge about it. The human scale is a fundamental fact in architectural design, and all design acts involve the designer being 'immersed' in the representation of the design. Immersion is a property of the design act and not of either the designer or the representational medium, since, as shown by the example of familiarity in the current, designers with the equivalent skill working in the same medium can be differently immersed in the design representation. Any specification of a design act must consist of an account of the nature of immersion it involves.

The role of the design representation has been studied extensively in design scholarship using the example of sketching. Sketching is the ubiquitous representational mode early in the design process. Representations externalize design ideas and assist in the cognitive economy of designing. Sketching as a specific mode enables this because of the speed and ease with which it enables designers to reorganize, restructure, augment and extend ideas. Studies of sketching have expanded the understanding of the role of the representation in design.

The advent of computing made it technically possible to explore the possibilities of spatial telepresence – the illusion of being present in a space different from the one which one physically occupies at a given point in time. These technological possibilities resulted in the development of immersive virtual environments such as HIS. They have also enabled theoretical work involved with formulating an understanding of what telepresence might entail and what technological features enable or inhibit it. This inquiry has resulted in the development of the twin concepts of presence (the illusion of being present in a different space from the one which is physically occupied) immersion (the capacity of the technology to enable the illusion of presence). This conception of immersion has been adopted for architectural design media which are sometimes classified into immersive and non-immersive types.

However, in the context of architectural design, an immersive design representation cannot be understood in terms of the concepts of immersion and presence without significant conceptual modification. The architect's involvement with the design representation occurs in the context of a design problem which forms the basis of a preferred situation which is different from the current situation. It is proposed that in the context of architectural design, immersion is a property of the design act, and not that of either the representational medium or the designer's virtuosity. Immersion during architectural design is the consequence of (a) the design representation accessed through a representational medium, (b) the design problem at hand, (c) knowledge available to the designer about the design problem and the design representation (known as 'context'). These only come together during the design act. Hence, immersion is a property of the design act.

A comparative study of a design time problem conducted at the design site and in the Hybrid Ideation Space (HIS) demonstrates this idea of immersion. The site, as it exists during the time problem is a part of the representational medium available to the designer, just as the 360-degree panorama of the site projected in HIS is a part of the representational medium. The mark making capacities of the respective media also forms part of the representational medium. These case studies demonstrate how the concept of immersion can be deployed an integral part of the general model of the design act. By considering immersion to be a property of the design act which describes and classifies different types of design acts, such as the cases in the site where the drawings were generative and the cases in the site where the site was generative, the concept of immersion is no longer merely a geometrical fact about the relationship between the designer and the design representation.

Sketching (making marks on a surface with a stylus by hand) remains the predominantly studied mode of representation in the early stages of architectural design. However, with technological advances, early phase architectural design may soon be possible by using parametric methods or other computational approaches which use digital augmentation of analog representations. The proposed model of the design act can be used to describe these processes.

Further refinement of the concept of immersion will require the design of narrower, more controlled experiments and testing with other design media such as virtual worlds. Collaborative design requires consideration of aspects of interpersonal communication and provides another avenue in which the proposed model of the design act and the proposed conception of immersion needs to be extended.

This dissertation contributes a medium-agnostic model of the design act and a conception of immersion as property of the design act and demonstrates how these can be deployed to study designing systematically.

Bibliography

Alexander, Christopher. *A Pattern Language: Towns, Buildings, Construction*. New York: Oxford University Press, 1977.

———. "Information and an Organized Process of Design." *Proceedings of the Building Research Institute*, no. Spring 1961 (1961): 115–24.

———. *Notes on the Synthesis of Form*. Harvard University Press, 1964.

———. "The State of the Art in Design Methods." *DMG Newsletter* 5, no. 3 (1971): 3–7.

Anderson, R.E., and T Helstrup. "Visual Discovery in Mind and on Paper." *Memory and Cognition* 21 (1993): 283–93.

Arnheim, R. "A Plea for Visual Thinking." *Critical Inquiry* 6, no. 3 (1980): 489–97.

Arnheim, Rudolf. *Visual Thinking*. 1st ed. University of California Press, 1969.

Asimov, Morris. *Introduction to Design*. Prentice-Hall Series in Engineering Design. Englewood Cliffs, N. J.: Prentice-Hall, 1962.

Athavankar, U. "Mental Imagery as a Design Tool." In *Proceedings of the Thirteenth European Meeting on Cybernetics and Systems*, II:382–87. Vienna, Austria: Austrian Society of Cybernetics and University of Vienna, 1996.

Bazin, Andre. *What Is Cinema?* Translated by Hugh Gray. Vol. 1. 2 vols. University of California Press, 1968.

Bergdoll, Barry, and Leah Dickerman. *Bauhaus 1919-1933: Workshops for Modernity*. New York: The Museum of Modern Art, 2009.

Bilda, Zafer, John S. Gero, and Terry Purcell. "To Sketch or Not to Sketch? That Is the Question." *Design Studies* 27, no. 5 (2006): 587–613.

Boulding, Kenneth Ewart. *The Image: Knowledge in Life and Society*. Ann Arbor: University of Michigan Press, 1956.

Bredekamp, H., R. Daalder, E. Chan, and C. Webb. *Gehry Draws*. Edited by M. Rappolt and R. Violette. MIT Press in association with Violette Editions, 2004.

Bruggen, C. van. *Frank O. Gehry: Guggenheim Museum Bilbao*. Guggenheim Museum Publications, 1998.

Carpo, Mario. *Architecture in the Age of Printing: Orality, Writing, Typography, and Printed Images in the History of Architectural Theory*. The MIT Press, 2001.

———. *The Alphabet and the Algorithm*. 1st ed. The MIT Press, 2011.

———, ed. *The Digital Turn in Architecture 1992-2012*. AD Reader. Chichester: Wiley, 2013.

Chastain, T., Y. E. Kalay, and C. Peri. "Square Peg in a Round Hole or Horseless Carriage? Reflections on the Use of Computing in Architecture." *Automation in Construction* 11, no. 2 (2002): 237–48.

Clark, Andy, and David Chalmers. "The Extended Mind." *Analysis* 58, no. 1 (1998): 7–19.

"Cognition, N." *OED Online*. Oxford University Press. Accessed July 28, 2018. http://www.oed.com/view/Entry/35876.

Cross, Nigel, Henri Christiaans, and Kees Dorst, eds. *Analysing Design Activity*. 1st ed. Wiley, 1997.

Crowther-Heyck, Hunter. *Herbert A. Simon: The Bounds of Reason in Modern America*. JHU Press, 2005.

Cuff, Dana. *Architecture: The Story of a Practice*. The MIT Press, 1992.

Dorta, Tomas. "Augmented Sketches and Models: The Hybrid Ideation Space as a Cognitive Artifact for Conceptual Design." In *Digital Thinking in Architecture, Civil Engineering, Archaeology, Urban Planning and Design: Finding the Ways*, 251–64. Montreal, Quebec: Europia Publishers, Paris, 2007.

———. "Ideation and Design Flow Through the Hybrid Ideation Space," 418–22. Mexico City, 2007.

Dorta, Tomas, Yehuda Kalay, Annemarie Lesage, and Edgar Perez. "Comparing Immersion in Remote and Local Collaborative Ideation through Sketches: A Case Study." In *Proceedings of the 14th International Conference on Computer Aided Architectural Design*, edited by Pierre Leclerq, Ann Heylighen, and Martin, 25–39. Liege: Les Éditions de l'Université de Liège, 2011.

———. "Design Conversations in the Interconnected HIS." In *Collaborative Management and Modelling for Design*, 83–93. Rome, Italy: Europia Publishers, Paris, 2011.

Dorta, Tomas, Annemarie Lesage, and Edgar Perez. "Point and Sketch: Collaboration in the Hybrid Ideation Space." In *Proceedings of the 20th International Conference of the Association Francophone d'Interaction Homme-Machine*, 129–36. Metz, France: ACM, New York, 2008.

Dorta, Tomas, Annemarie Lesage, Edgar Perez, and J. M. Christian Bastien. "Signs of Collaborative Ideation and the Hybrid Ideation Space." In *Design Creativity 2010*, edited by Toshiharu Taura and Yukari Nagai, 199–206. London: Springer, 2010.

Dourish, Paul. *Where the Action Is: The Foundations of Embodied Interaction*. Cambridge, Mass: MIT Press, 2001.

Dreyfus, Hubert L. "How Far Is Distance Learning From Education?" In *The Philosophy of Expertise*, edited by Evan Selinger and Robert P. Crease, 196–212. New York: Columbia University Press, 2006.

———. *On the Internet*. 2nd ed. Routledge, 2008.

Dreyfus, Hubert L., and Stuart E. Dreyfus. *Mind Over Machine*. Free Press, 1988.

Eastman, Charles. "University and Industry Research in Support of BIM." Report on Integrated Practice. American Institute of Architects, 2006. http://www.aia.org/SiteObjects/files/2_Eastman.pdf.

Eastman, Charles M. *Building Product Models: Computer Environments Supporting Design and Construction*. Boca Raton, Fla: CRC Press, 1999.

Eastman, Charles M. "The Use of Computers Instead of Drawings in Building Design." *AIA Journal* 63, no. 3 (1975): 46–50.

Eisenstein, Elizabeth L. *The Printing Press as an Agent of Change*. First Paperback Edition. Vol. (Vol 1 and 2). Cambridge, UK: Cambridge University Press, 1980.

Ericsson, Karl Anders, and Herbert Alexander Simon. *Protocol Analysis: Verbal Reports as Data*. MIT Press, 1993.

Ferguson, Eugene S. *Engineering and the Mind's Eye*. The MIT Press, 1994.

Finke, R. *Creative Imagery: Discoveries and Inventions In Visualization*. Hillsdale: Erlbaum, 1990.

Finke, Ronald A. "Theories Relating Mental Imagery to Perception." *Psychological Bulletin* 98, no. 2 (September 1985): 236–59.

Fish, J., and S. Scrivener. "Amplifying the Mind's Eye: Sketching and Visual Cognition." *Leonardo* 23, no. 1 (1990): 117–26.

Galison, Peter. "Aufbau/Bauhaus: Logical Positivism and Architectural Modernism." *Critical Inquiry* 16, no. 4 (1990): 709–52.

———. "The Ontology of the Enemy: Norbert Wiener and the Cybernetic Vision." *Critical Inquiry* 21, no. 1 (1994): 228–66.

Galison, Peter, and David J. Stump, eds. *The Disunity of Science: Boundaries, Contexts, and Power*. 1 edition. Stanford, Calif: Stanford University Press, 1996.

Gallagher, Shaun. "Philosophical Antecedents of Situated Cognition." In *Cambridge Handbook of Situated Cognition*, edited by Philip Robbins and Murat Aydede, 35–51. Cambridge; New York: Cambridge University Press, 2009.

Gardner, Howard. *The Mind's New Science: A History of the Cognitive Revolution*. Basic Books, 1985.

Gaver, William W. "Technology Affordances," 79–84. ACM Press, 1991.

Gero, John S. "Design Prototypes: A Knowledge Representation Schema for Design." *AI Magazine* 11, no. 4 (December 15, 1990): 26.

Gero, John S., and Udo Kannengiesser. "The Situated Function–Behaviour–Structure Framework." *Design Studies* 25, no. 4 (July 2004): 373–91.

Gibson, James Jerome. *The Ecological Approach to Visual Perception*. Houghton Mifflin, 1979.

Goel, Vinod. *Sketches of Thought*. Cambridge, Massachusetts: The MIT Press, 1995.

Goffman, Erving. *The Presentation of Self in Everyday Life*. 1st ed. Anchor, 1959.

Goldschmidt, G. "Serial Sketching: Visual Problem Solving in Designing." *Cybernetics and Systems* 23, no. 2 (1992): 191–219.

———. "The Dialectics of Sketching." *Creativity Research Journal* 4, no. 2 (1991): 123–43.

Goldschmidt, Gabriela. "Cognitive Economy in Design Reasoning." In *Human Behaviour in Design*, 53–62. Springer, Berlin, Heidelberg, 2003.

———. *Linkography: Unfolding the Design Process*. 1 edition. Cambridge, Massachusetts: The MIT Press, 2014.

———. “Modeling the Role of Sketching in Design Idea Generation.” In *An Anthology of Theories and Models of Design*, edited by Amaresh Chakrabarti and Lucien T. M. Blessing, 433–50. London: Springer, 2014.

———. “The Backtalk of Self-Generated Sketches.” *Design Issues* 19, no. 1 (2003): 72–88.

Goodman, Nelson. *Languages of Art: An Approach to a Theory of Symbols*. 2nd ed. Indianapolis: Hackett Publishing Company, 1976.

Guttag, John V. *Introduction to Computation and Programming Using Python*. Revised and expanded edition. Cambridge, Mass.: The MIT Press, 2013.

Hartman, Tilo, Werner Wirth, Peter Vorderer, Christoph Klimmt, Holger Schramm, and Saskia Bocking. “Spatial Presence Theory: State of the Art and Challenges Ahead.” In *Immersed in Media: Telepresence Theory, Measurement & Technology*, 115–35. Springer International Publishing, 2015.

Herbert, Daniel M. “Graphic Processes in Architectural Study Drawings.” *Journal of Architectural Education* 46, no. 1 (1992): 28–39.

———. “Study Drawings in Architectural Design: Their Properties as a Graphic Medium.” *Journal of Architectural Education* 41, no. 2 (1988): 26–38.

Hutchins, Edwin. *Cognition in the Wild*. Cambridge, Mass: MIT Press, 1995.

———. “How a Cockpit Remembers Its Speeds.” *Cognitive Science* 19, no. 3 (July 1995): 265–88.

Ijsselsteijn, WA, and G. Riva. “Being There: The Experience of Presence in Mediated Environments.” *EMERGING COMMUNICATION* 5 (2003): 3–16.

Itten, Johannes. *Design and Form: The Basic Course at the Bauhaus and Later*. Rev. ed. New York: Van Nostrand Reinhold, 1963.

Ivins, William M. *On the Rationalization of Sight*. Da Capo Press Inc, 1976.

Johnson, Gabe, Mark D. Gross, Jason Hong, and Ellen Yi-Luen Do. “Computational Support for Sketching in Design: A Review.” *Foundations and Trends® in Human-Computer Interaction* 2, no. 1 (2007): 1–93.

Jones, J. Christopher. “How My Thoughts about Design Methods Have Changed during the Years.” *Design Methods and Theories* 11, no. 1 (1977): 48–62.

Jones, J. Christopher, and D. G. Thornley, eds. *Conference on Design Methods; Papers*. Oxford, New York: Macmillan, 1963.

Kalay, Yehuda E., ed. *Computability of Design*. John Wiley & Sons, 1987.

———. *Architecture’s New Media*. Cambridge, Massachusetts: MIT Press, 2004.

———. “The Impact of Information Technology on Design Methods, Products and Practices.” *Design Studies* 27, no. 3 (May 2006): 357–80.

Kaptelinin, Victor, and Bonnie Nardi. “Affordances in HCI: Toward a Mediated Action Perspective.” In *Proceedings of the 2012 ACM Annual Conference on Human Factors in Computing Systems*, 967–976. CHI ’12. New York, NY, USA: ACM, 2012.

Kostof, Spiro. *A History of Architecture: Settings and Rituals*. 2nd ed. Oxford University Press, USA, 1995.

Kunz, Werner, and Horst W. J Rittel. *Issues as Elements of Information Systems*. Working Paper - Center for Planning and Development Research, University of California, no. 131. Berkeley: Institute of Urban and Regional Development, University of California, 1970.

Lakoff, George. *Metaphors We Live By*. Chicago: University of Chicago Press, 1980.

Larkin, Jill H., and Herbert A. Simon. "Why a Diagram Is (Sometimes) Worth Ten Thousand Words." *Cognitive Science* 11, no. 1 (1987): 65–100.

Latour, Bruno. "A Cautious Prometheus? A Few Steps toward a Philosophy of Design (with Special Attention to Peter Sloterdijk)." In *Networks of Design: Proceedings of the 2008 Annual International Conference of the Design History Society (UK)*, 2–10. University College, Falmouth, Cornwall: Universal Publishers, 2008.

———. "Drawing Things Together." In *Collection*, 19–68. MIT Press, 1990.

Lombard, M., and T. Ditton. "At the Heart of It All: The Concept of Presence." *Journal of Computer-Mediated Communication* 3, no. 2 (1997).

Lombard, Matthew, Frank Biocca, Jonathan Freeman, Wijnand IJsselsteijn, and Rachel J. Schaevitz, eds. *Immersed in Media: Telepresence Theory, Measurement & Technology*. Springer International Publishing, 2015.

Lynn, Greg. *Folds, Bodies & Blobs: Collected Essays*. Bruxelles: La Lettre volée, 1998.

Maher, Mary Lou, Simeon J. Simoff, and Anna Cicognani. *Understanding Virtual Design Studios*, 2000.

Marr, David. *Vision: A Computational Investigation into the Human Representation and Processing of Visual Information*. W. H. Freeman, 1983.

Maynard, Patrick. *Drawing Distinctions: The Varieties of Graphic Expression*. Ithaca, N.Y: Cornell University Press, 2005.

McGrenere, Joanna, and Wayne Ho. "Affordances: Clarifying and Evolving a Concept." In *Proceedings of Graphics Interface 2000*, 179–186, 2000.

McLuhan, Marshall. *Understanding Media: The Extensions of Man*. McGraw-Hill, 1964.

Minsky, M. "Telepresence." *Omni* 2, no. 9 (1980): 45–52.

Naylor, Gillian. *The Bauhaus Reassessed: Sources and Design Theory*. New York: E.P. Dutton, 1985.

Negroponte, Nicholas. *Soft Architecture Machines*. Cambridge, Mass: The MIT Press, 1975.

Network Practices: New Strategies in Architecture and Design. 1st ed. New York: Princeton Architectural Press, 2007.

Newell, Allen, J. C. Shaw, and Herbert A. Simon. "Elements of a Theory of Human Problem Solving." *Psychological Review. Vol 65(3)*, 1958, 151–66.

Newell, Allen, and H. A. Simon. "Computer Simulation of Human Thinking and Problem Solving." Santa Monica, California: The RAND Corporation, 1961.

Noble, Douglas, and Horst W. J Rittel. "Issue-Based Information Systems for Design." Working Paper. Institute for Urban & Regional Development. Berkeley, California: University of California, Berkeley, 1989.

Norman, Donald A. *The Design of Everyday Things*. 1st Doubleday/Currency ed. New York: Doubleday, 1990.

Palmer, Stephen E. *Vision Science: Photons to Phenomenology*. 1st ed. The MIT Press, 1999.

Panofsky, Erwin. *Perspective as Symbolic Form*. Translated by Christopher Wood. Zone Books, 1993.

"Perception, N." *OED Online*. Oxford University Press. Accessed July 28, 2018. http://www.oed.com/view/Entry/140560.

Perez-Gomez, Alberto, and Louise Pelletier. *Architectural Representation and the Perspective Hinge*. 1st ed. The MIT Press, 2000.

Peri, Christopher Anthony. "Impact of Media on Spatial Communication: From Paper to Collaborative Virtual Environments." Ph.D. Dissertation, University of California, Berkeley, 2003.

Picon, Antoine. *Digital Culture in Architecture: An Introduction for Thedesign Professions*. Boston, MA: Birkhaeuser, 2010.

Pols, Auke J.K. "Characterising Affordances: The Descriptions-of-Affordances-Model." *Design Studies* 33, no. 2 (March 2012): 113–25.

Protzen, Jean-Pierre, and Christopher A. Alexander. "Value in Design: A Dialogue." *Design Studies* 1, no. 5 (July 1980): 291–98.

Protzen, Jean-Pierre, and David J. Harris. *The Universe of Design: Horst Rittel's Theories of Design and Planning*. 1st ed. Routledge, 2010.

Reas, Casey, and Ben Fry. *Processing: A Programming Handbook for Visual Designers and Artists*. MIT Press, 2014.

Rittel, Horst W. J. "On the Planning Crisis: Systems Analysis of the First and Second Generations." *Bedrifsokonomen* 8 (1972): 390–96.

Rittel, Horst W. J. "The Reasoning of Designers." Boston, MA, 1987.

Rittel, Horst W. J., and Melvin M. Webber. "Dilemmas in a General Theory of Planning." *Policy Sciences* 4, no. 2 (1973): 155–69.

Robbins, Edward. *Why Architects Draw*. Cambridge, Mass: MIT Press, 1994.

Robbins, Philip, and Murat Aydede, eds. *The Cambridge Handbook of Situated Cognition*. Cambridge; New York: Cambridge University Press, 2009.

Rosch, Eleanor, and Barbara Bloom Lloyd, eds. *Cognition and Categorization*. L. Erlbaum Associates, 1978.

Schnabel, Marc A., and Thomas Kvan. "Spatial Understanding in Immersive Virtual Environments." *International Journal of Architectural Computing* 1, no. 4 (December 1, 2003): 435–48.

Schön, Donald A. *The Design Studio: An Exploration of Its Traditions and Potentials*. Architecture & the Higher Learning. London: RIBA Publications Ltd., 1985.

Schon, Donald A. *The Reflective Practitioner: How Professionals Think in Action*. Basic Books, 1983.

Schon, Donald A., and Glenn Wiggins. "Kinds of Seeing and Their Functions in Designing." *Design Studies* 13, no. 2 (1992): 135–56.

Selinger, Evan, and Robert P. Crease, eds. *The Philosophy of Expertise*. New York: Columbia University Press, 2006.

Shapiro, Lawrence A. *Embodied Cognition*. New Problems of Philosophy. New York: Routledge, 2011.

Sheridan, T. B. "Musings on Telepresence and Virtual Presence." *Presence: Teleoperators and Virtual Environments* 1, no. 1 (1992): 120–26.

Simon, Herbert A. "Bradie on Polanyi on the Meno Paradox." *Philosophy of Science* 43, no. 1 (1976): 147–50.

———. *Models of Man: Social and Rational; Mathematical Essays on Rational Human Behavior in Society Setting*. New York: Wiley, 1957.

———. "Rationality as Process and as Product of Thought." *The American Economic Review* 68, no. 2 (1978): 1–16.

———. "The Logic of Rational Decision." *The British Journal for the Philosophy of Science* 16, no. 63 (1965): 169–86.

———. *The Sciences of the Artificial*. Cambridge, Massachusetts: MIT Press, 1969.

———. "The Structure of Ill Structured Problems." *Artificial Intelligence* 4, no. 3–4 (1973): 181–201.

Slater, Mel. "Immersion and the Illusion of Presence in Virtual Reality." *British Journal of Psychology* 109, no. 3 (2018).

Slater, Mel, and Sylvia Wilbur. "A Framework for Immersive Virtual Environments (FIVE): Speculations on the Role of Presence in Virtual Environments." *Presence: Teleoperators and Virtual Environments* 6, no. 6 (1997): 603–16.

Suchman, Lucille Alice. *Human-Machine Reconfigurations*. Cambridge University Press, 2007.

Sutherland, I.E. "SketchPad: A Man-Machine Graphical Communication System." In *AFIPS Conference Proceedings*, 23:323–28, 1963.

Suwa, Masaki, and Barbara Tversky. "What Do Architects and Students Perceive in Their Design Sketches? A Protocol Analysis." *Design Studies* 18, no. 4 (1997): 385–403.

Terzidis, Kostas. *Algorithms for Visual Design Using the Processing Language*. John Wiley & Sons, 2009.

Thomas, Nigel J. T. "Mental Imagery." Edited by Edward N. Zalta. *The Stanford Encyclopedia of Philosophy*. Metaphysics Research Lab, Stanford University, 2017. https://plato.stanford.edu/archives/spr2017/entries/mental-imagery/.

Tversky, Barbara. “Spatial Cognition: Embodied and Situated.” In *The Cambridge Handbook of Situated Cognition*, edited by Philip Robbins and Murat Aydede, 201–16. Cambridge; New York: Cambridge University Press, 2009.

Varela, Francisco J., Evan T. Thompson, and Eleanor Rosch. *The Embodied Mind: Cognitive Science and Human Experience*. New edition. The MIT Press, 1992.

Verstijnen, I. M., C. van Leeuwen, G. Goldschmidt, R. Hamel, and J. M. Hennessey. “Creative Discovery in Imagery and Perception: Combining Is Relatively Easy, Restructing Takes a Sketch.” *Acta Psychologica* 99, no. 2 (1998): 177–200.

Verstijnen, IM, C van Leeuwen, G Goldschmidt, R Hamel, and JM Hennessey. “Sketching and Creative Discovery.” *Design Studies* 19, no. 4 (1998): 519–46.

Vesely, D. *Architecture in the Age of Divided Representation: The Question of Creativity in the Shadow of Production*. Cambridge, Massachusetts: MIT Press, 2004.

Whyte, Jennifer. *Virtual Reality and the Built Environment*. 1st edition. Oxford: Routledge, 2002.

Wigley, Mark. “Network Fever.” *Grey Room* (2001): 82–122.

Yaneva, Albena. “From Reflecting-in-Action Towards Mapping of the Real.” In *Transdisciplinary Knowledge Production in Architecture and Urbanism: Towards Hybrid Modes of Inquiry*, edited by Isabelle Doucet and Nel Janssens, 117–28. Urban and Landscape Perspectives, v. 11. New York: Springer, 2011.

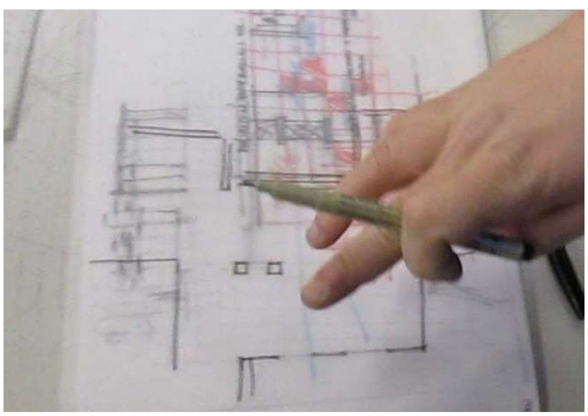
———. *Mapping Controversies in Architecture*. Burlington: Ashgate Pub. Co, 2012.

APPENDIX

Wurster Site – 1 (WS1) (D)

So, in the first sheet I look at what the basic space looks like. I come here a lot, so I already know what's going on. I guess, passively, I can already assume a whole bunch of things about the lobby. I lay myself out a grid, I assemble the material bits of the space on the grid, and from there I start to make small assumptions about how people move through the space, for instance, where I remember people collecting. So, I do a lot of memory calls. We're not sitting here for hours so I can't really do an analysis and I can't do video, so I just have what's in my head to draw from. So, I assemble this, and from here I just work on maybe getting sections, that can allow me to see height and space.

This (development of **Error! Reference source not found.**, right) is basically an idea of people density, so that's how I started. I am interested in the social capital of places. This is obvious, the whole Ramona's, outside where people are coming from, it's not about, oh people do this here. It is obvious what people do here. People move from the door to the elevators, and from the door to the bathrooms. The one thing about this space is that I get lot very easily. I think when I first came here I didn't really know what was going on. That's because nothing really is informative down here. So, my idea is that you kind of get collected outside. From doing this analysis I worked through a number of steps about the space. I think I draw the space over and over again. I don't necessarily draw anything in the space, but I draw the space, repetitively.



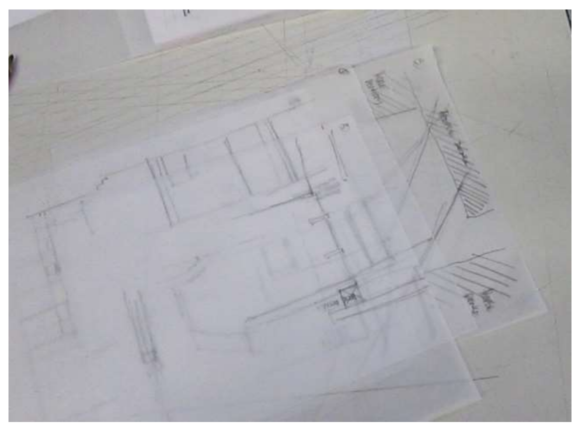
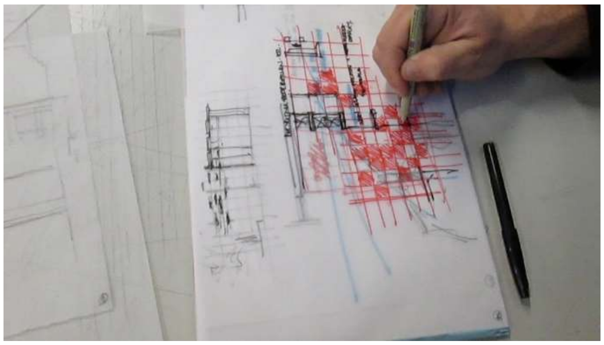


Figure 23: Layout and sections, drawn repeatedly as a study of the space

I run through a lot of scenarios in my head about how the space is being used. I'm quite claustrophobic, so if someone is doing things to the roof [ceiling] or doing installations above my head I become uncomfortable, so I tend to avoid that, specifically in here because the heights are pretty limited. But outside, that's where I found that I could work with these. So, what I have is two main things – critical flow and critical collections for this space. Areas of critical flow is this door here. So, its everybody coming through the door, wherever they're going to, the lecture hall or the toilets or whatever. So, what happens is that you get this collection here in the lobby. So, I'd like to move this entrance inwards, create a new entrance to Ramona's, remove this silly thing [points to the notice board]. Basically, this becomes a closed faced from here, to here. So, this space gets bigger – the recycling, book returns and all those things. Over here, around these columns, I sort of feel obliged to put a reception here, because that was my first experience here

– coming here and not knowing that the reception is upstairs. Even though there's signage, but the signage is also ugly. As you say, it's a bit of a hodge-podge. In that you miss a lot of details. Collecting all the media – all the posters and all the announcements in one place, and when you come in you can may be speaking to someone, so they can direct you correctly. I'll do some sort of assembly around these two pillars. I can imagine this must have been quite an amazing space before they added the retrofit. So, I'll wrap information around this assembly, and maybe more information, more media collection next to the walls. I know that the entrance to the café can be noisy, so maybe changing that entrance in the process as well.



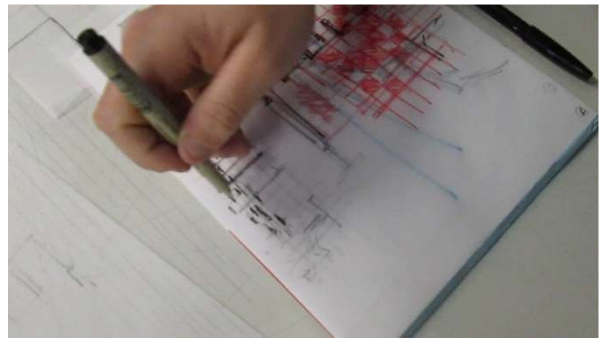


Figure 24: Left: Showing the redesign of the entrance. The main entrance is moved with new transparent and blank facades. Right: Showing the steel grid.

And then finally, I'd like to extend this grid [points to the concrete grid on the ribbed ceiling] outside. The grid will drop down, I can imagine using steel and then extending it out and change in height. This is what I'm showing here [points to section]. The steel mesh gets caught in here [points to the proposed expanded entrance] and the rises again once it goes inside.

Wurster Site – 2 (WS2)

"I started thinking that, as is, the lobby accomplishes most of the goals that you were looking for. So, I suspected that my intervention would be minimal. I was worried about that, that I would not propose a broad enough or radical enough change. But I really like being able to see through the building and I wanted to keep that visual access. And I was fine with where the entries and exits were and felt like things moved Ok. So, I was mostly concerned with the information dissemination and display of energy information and waste. I started thinking about, because I didn't really want to change circulation patterns and put down new walls or close things off anymore, I started thinking about the overhead canopy and the ground plane but couldn't figure out where you would be lighting them that would show interesting information. So, they became about screens.

Before, I thought the screens would be tiles. There would be a hard edge but there would be an area where the screen bled into the surface. So, this whole area would be screen tiles. (Points to the floor of the lobby). And they would track information. And I never really pinned down exactly how or what information would be important or how to show it. I thought maybe you could show how many lights were in the building because they (the tiles) would glow red, or something like that. Or maybe they would flow, or track patterns, so as you walked maybe they would trail lights behind you. And then the overhead screen I thought would fold down from the railing and either replace that (the railing) or hang in front of it. Written information would run across and as it folded under it become more of an interactive screen like floor tiles. And then it could fold down here (walks to the double column) and it could have information and wrap around here (around the double column). For a long time, I couldn't figure out if the waste could be here (stands between the two columns of the double column, indicates that the space between the two columns is too narrow to walk through). So just fill it with stuff. But then I ended up deciding that I wanted to cut a hole in the floor here (walks towards the elevator lobby, the lobby space between the two lobbies, points to the floor above) and build a garbage chute, so that there was some kind of shaft which collected the garbage. It could be backlit, and I didn't know how to make this not disgusting, but there would be this possibility of shadow puppets with the trash. So that was basically it.

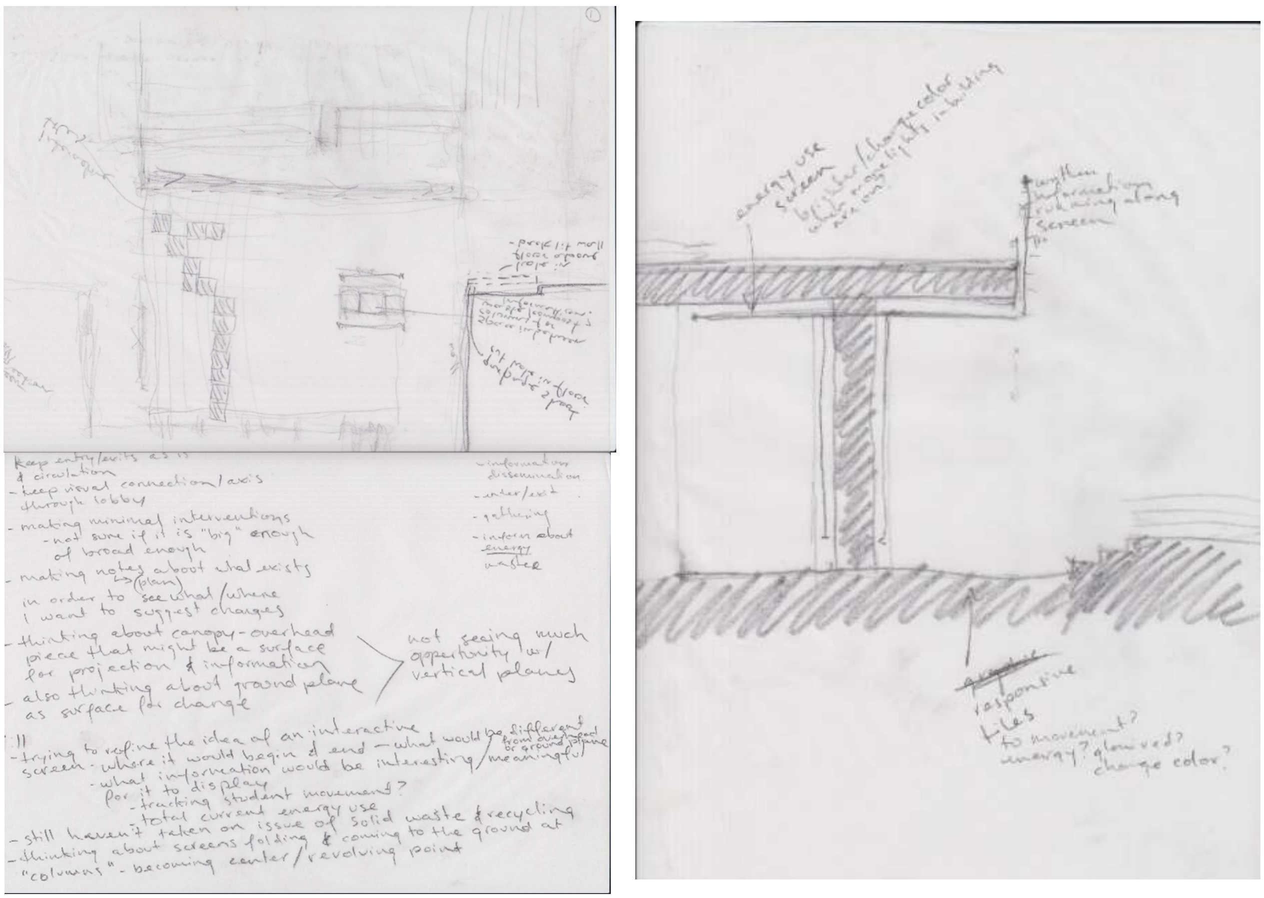


Figure 25: Working sketches at the site

The participant made the following notes as part of her proposal (see **Error! Reference source not found.**, left-bottom):

- Keep entry/exits as is & circulation
- Keep visual connection/axis through lobby
- Making minimal interventions – not sure if its "big" enough or broad enough
- Making notes (plan) about what exists in order to see what/where I want to suggest changes.
- Thinking about canopy-overhead piece that might be a surface for projection of information
- Also thinking about ground plane as surface for change

- (on the above two points) – not seeing much opportunity with vertical planes.
- Trying to refine the idea of an interactive screen where it would begin and end – what would be different?
- What information would be interesting/meaningful for it to display
- Tracking student movement.
- Still haven't taken on issue of solid waste and recycling
- Thinking about screens folding and coming to the ground as "columns" – becoming center/revolving point.

Wurster Site – 3 (WS3)

I started with reading the hand out to find out what I had to achieve. The beginning was also about understanding the site itself, the lobby, sketching it out in plan just to understand the lobby, the movement, because I thought the lobby itself is an area where circulation is most important. This was the departure point of this exercise for me. I labeled each area of the entry and exit of the space and then using that maybe as a palette to design the installation. I guess the other approach was, what I asked you in the beginning, just how much do we need to change. And I thought I preferred a minimalist approach. Rather than destroying and remodeling the lobby I would rather add things to it.

I just wanted to separate the actual sketch of the lobby from the exercise for now and look at the circulation points. Generally, the area of intersection and the largest concentration of circulation. Noting the columns as an area that people always move around and use that as a spot. I also took notes as I went along for myself. I wanted to maintain the integrity of the structure and a large intervention was not ideal. At that point I wanted to stop and just look at what kind of information, or what I also wanted to achieve within the lobby. Obviously not just for circulation but at the end there needs to be a program. From that plan I thought visual permeation and visual access is also very important in circulation because your eyes are really what moves you through the space.

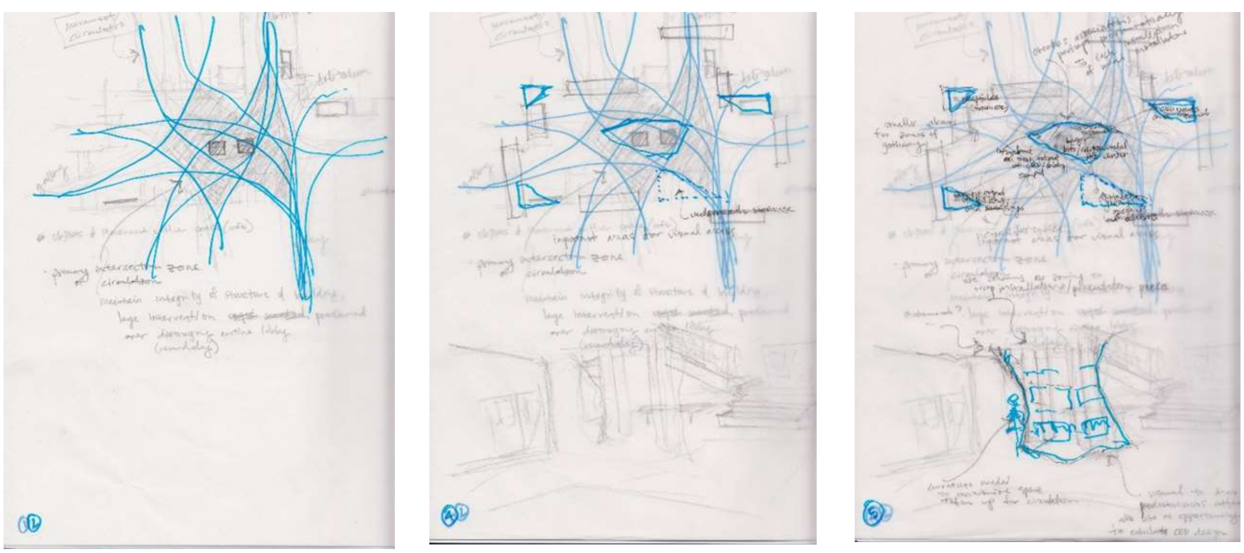


Figure 26: Study of circulation and visual access patterns, and subsequent design development

Going back to the plan I sketch out a really simple perspective of the space just trying to envision myself. But also making it more of a homogenous space rather than a tree like element in the center. These elements (points to a series of peripheral elements in the plane) sort of compile everything together into one larger space without inhibiting the circulation through it.

So then, I wanted to begin to insert program into this arrangement. This time dividing them into spaces (this drawing shows the interventions, but not the underlying plan) so that if a receptacle will be here, information about the receptacle will be there so that there's a connection between all of it, joining the space together.

I have no idea about the design or the "look" of it, but I guess this exercise is more about establishing what I wanted to be there.

Q: Did you think that being familiar with the site helped you?

P: I think that's also why I didn't really get up to look at it. I think I only got up to double check a couple of things.

Kroeber Site – 1 (KS-1)

I started with looking at the prompt and reading it over a few times, obviously. Having not spent a ton of time in the space I wanted to just orient myself to what was being asked of it. Given these categories I tried to map out the space and how they were addressed or weren't addressed. [categories:] Circulation, entrance/exit, a place for gathering, the information display, and also the energy and waste area. So, the two items that I think were being addressed the least were gathering and the energy and waste displays.

Just sketching out the plan of the space got messed up here and down here (points to drawing). But, kind of categorizing circulation - how I saw people using the space. It was kind of surprising how many people were in the stairwell and not in the general lobby area. And then, since Kroeber is the Art building I wanted to maintain this identity that they have of presenting their students' art and displaying it. So, I was coding where that was happening (points to part of the drawing). This is just the TV (points to TV in the drawing next to displays). I guess this is just a TV, unless they do video art. These are paintings displayed on the wall (points to drawing). Although I didn't see it at first, this is the big classroom with a lot of in and out [the class ended while the student was working on the proposal, so the effect of this on the lobby could be experienced.] It was surprising. It [the entrance to the classroom] seemed like a back of the house closet. Not that it needs to be but it [the classroom entrance] did not present itself volumetrically in the space. I would have anticipated this (points to a door on the drawing next to the door to the classroom) being the big class in here. But it was just a smaller classroom.

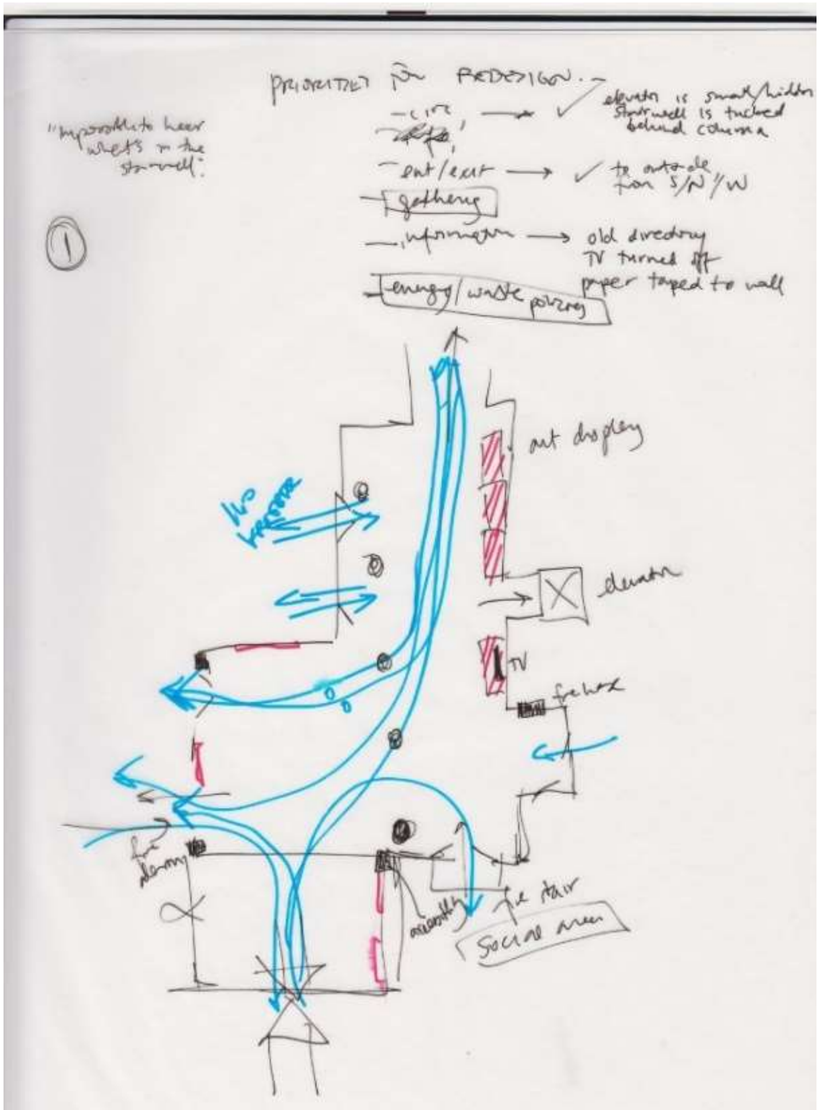


Figure 27: The participant's study of circulation in the space as perceived at the Site

Then I guess I took a step outside to disassociate and thought about how we could leverage the strengths of how this space is being currently used for the purposes of this design project - gathering and circulation - and see how we can adjust it to better address those issues that aren't working so well. So, first being the stairwell which was filled with 10 people chatting with each other, but no one was out here (points to the lobby), expect for, there was two people who had snuck out of this classroom that were chatting about something different and then they went back in. So, they were just using this (points to the lobby) as a place for privacy, instead of as a bigger place for gathering. So, opening up this to be more of a natural progression through the building, and then thinking about the entrances, 160 (classroom) is a classroom where its more slipping in and entering through this axis, so that instead of cutting out or coming out into this busy circulation space you can more or less slip into that axial circulation stream (Figure 14).

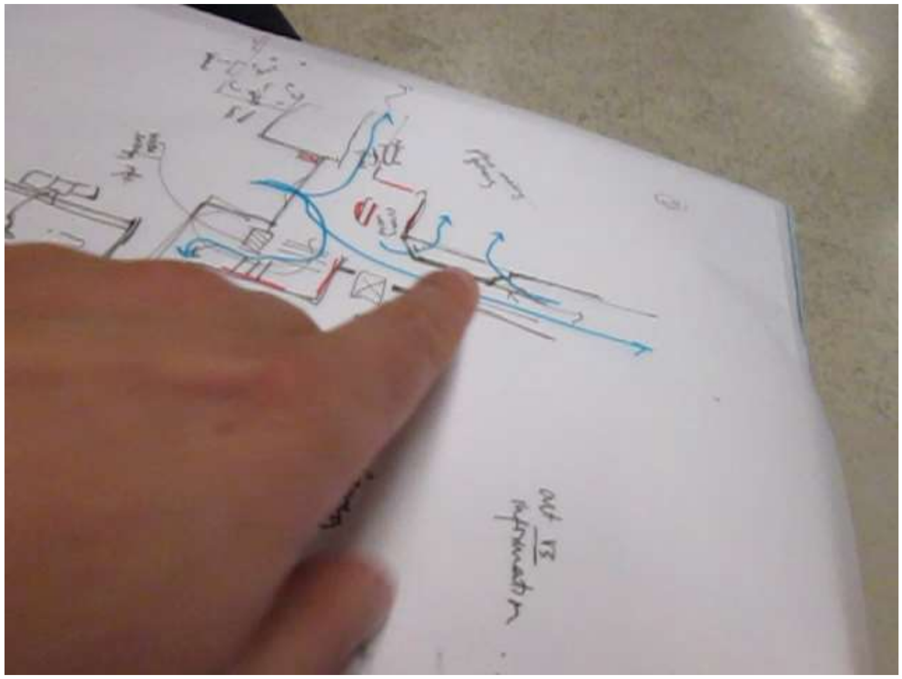


Figure 28: Shows how the entrance to 160 opens "into the axis" instead of opening out into the lobby.

At this stage I was not concerned about the columns. I also thought about sub-dividing this big space to make more natural areas of gathering and perhaps more surfaces to display art and creating these planes, almost the way Wurster works, in that, this area is separate from that but it's still continuous (refers to a space in Wurster). So, letting that serve that purpose. Visually when you enter there's art in front of you, but behind that, can be seating area while you are waiting for class.

Figure 29: View of entrance drawn by participant

And then, I don't know why I did this, but I sketched the exterior of the entrance as if it were just a transparent plane which it is now, but obviously it can't act as transparent, and I sketched it, to see how the stairs could kind of come up and be visible from entrance. This layered privacy area behind this zone of art display perhaps, and then this double corridor which is main circulation and then this interior corridor to get to the classroom, and then the other corridor goes out this way (points to the left in the picture).

This is a horrible sketch. So, this is the exterior, zooming in to, once you're inside the doors. I don't actually think this is that useful. It would have been better if I had taken it from an angle from which you could see the stairs. I don't like it that much.

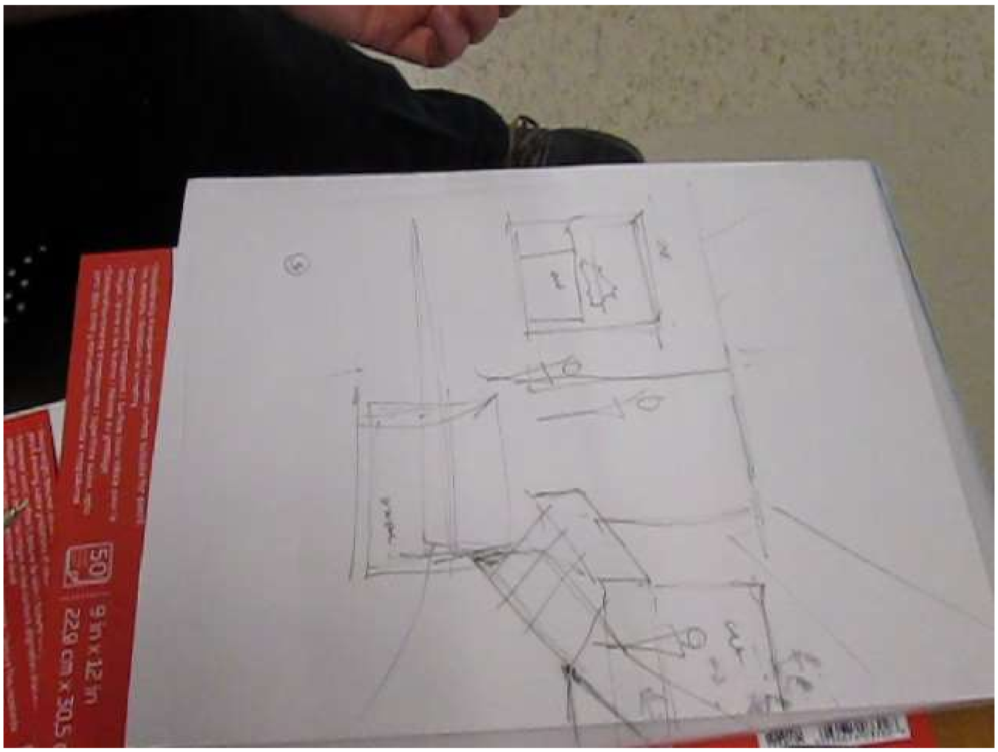


Figure 30: Third Sketch of the entrance, of area inside the door

So, this is the final proposal (Figure 18). Having peeked inside and seen all those people waiting for class, a nice way to integrate this gathering area would be to add some benches. Otherwise, pretty similar to what I sketched before, this corridor (the blue arrow) entering into 160 and further this second corridor going deeper into the building. And this is a separate zone. I initially put this forward but then realized that it was interfering with the door. I felt that the waste area would be best positioned by the entrance, because that's easy access for students and also a natural place when you are coming down the stairs. That's the elevator, and this is the energy information board (points to the position marked next to the elevator), which I think is effective positioning, while waiting for the elevator. You're not going to stop on your way to the elevator to look at that. You'll stop to look at art (points to the art displays, marked in red, on the drawing) but you might look at the energy information if you're waiting for the elevator anyway. The red still signifies the art. And that's about it.

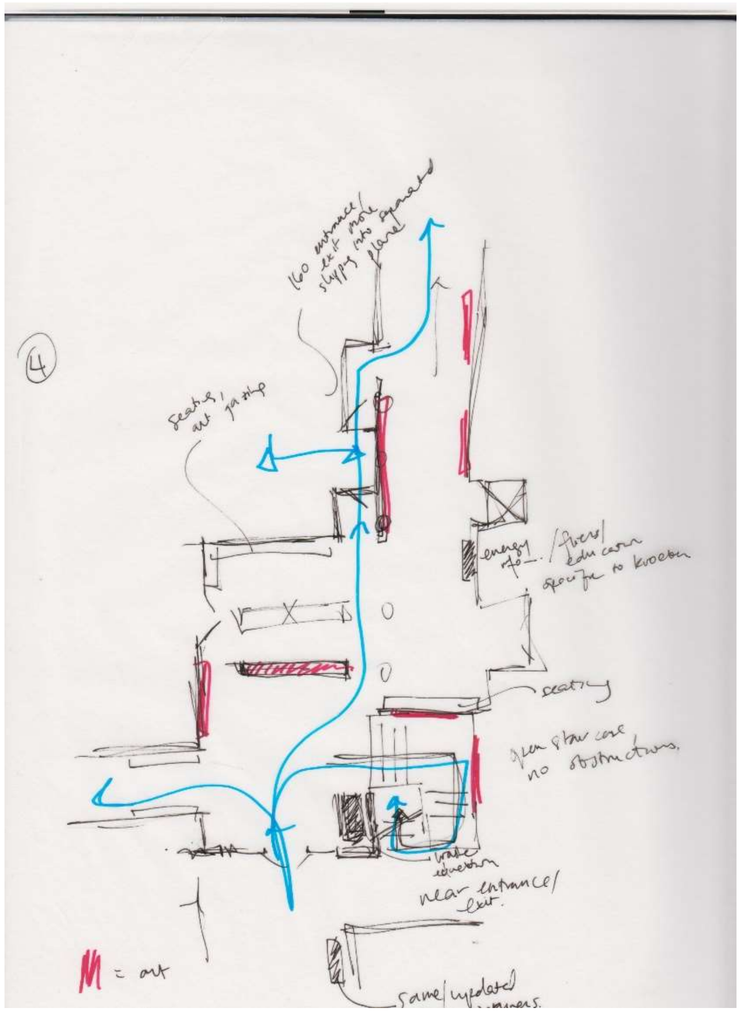


Figure 31: Final Proposal

Kroeber Site – 2 (KS2)

To start with, I didn't know what any of these rooms are, so I was basically getting organized with the basic arrangement. Then I worked out which rooms are what and how people move around and try to find places where it feels natural for people to just sit down. So that's what I did there (refers to the first two sketches).

And then I was trying to think about the different types of things a lobby place should do. It should be a place for the building to exhibit its work and show what goes on inside. It should be a place where you can figure out where you are trying to go – some sort of more practical information. It should be a place where people can meet each other and gather and hang out and also a place where the University can start really using more digital technology and stuff like that for communication, and also maybe the art work itself. So those were the things I started thinking about. It is easiest for me to move into perspective drawings. So, I started with the wall, just drawing what it looks like and a couple of benches. But first, I worked on my preliminary drawings using an overlay and was zoning out the different areas. And then I started working on the perspective drawings (Figure 34).

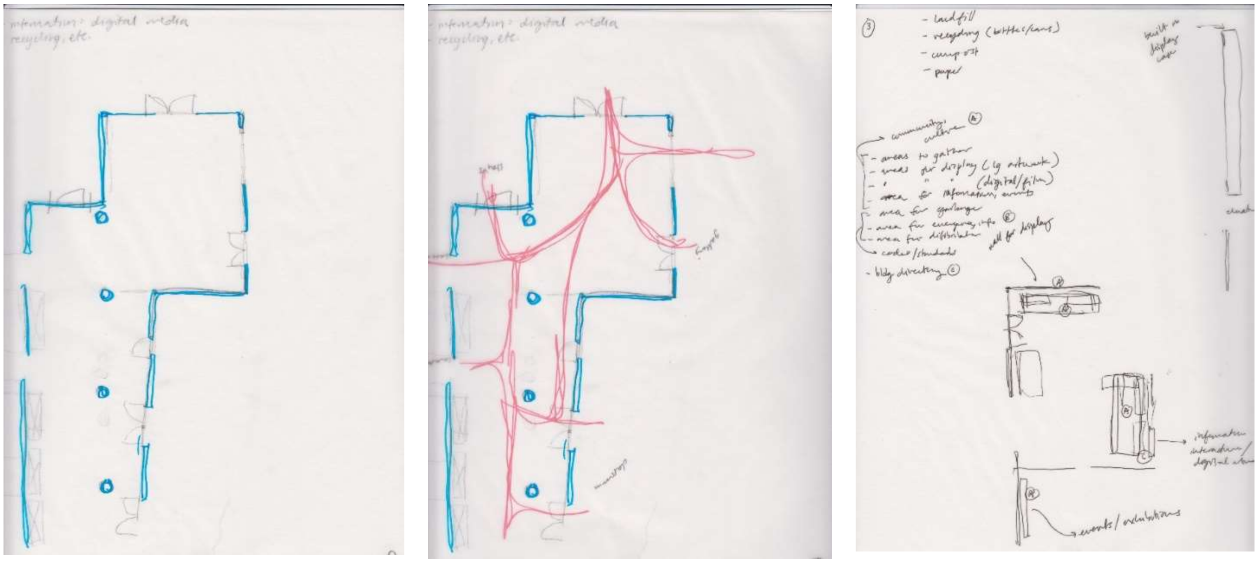


Figure 32: Preliminary sketch demarcating openings to the corridor space (left), and a preliminary look at the various circulation patterns on discovering where the different openings lead (middle). A further overlay (right) shows an attempt to zone different are

I was trying to figure out how things could be rotated through and change over time. And then I added another sheet. I had to move so that I could see what the wall looks like. It seems like this wall (**Error! Reference source not found.**) that is on the south side of the lobby space is really important, because there's this gallery right here where I assume a lot of work gets exhibited and sort of like the auditorium in Wurster there's a lot of activity there. But you would never know this if it was closed like it is today. Making the doors more open and moving the bulletin information which are in the hallway and already pretty hidden out to this wall would help. And also, since it is the south side, this would also be a good place for the monitors without too much glare. This could be posters and bulletins and seeing this wall as a place to learn about what's happening. And then, I thought the garbage could be moved out. It looks like there's a classroom behind that hallway but if the garbage could be sunk into the wall so that no one would trip over it, it would make it close enough to everything that's going on in the gallery but keep in out of sight.

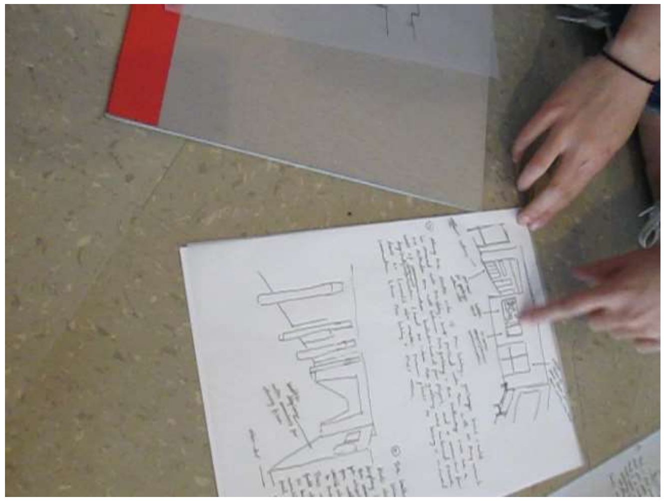


Figure 33: The "South" wall

And then, in this weird, long hallway/lobby space (points to the lower drawing in Figure 34, I was not totally sure what to do about it, but to change the ‘blockiness’ of the exhibition spaces and make the wall come out so that it does not feel like a crowded space (which it currently does due to the ‘blocky’ displays). And that could also be a place for video and TV screens, since it’s pretty dark. And then I decided to summarize what I had in mind and located these sketches on the plan.

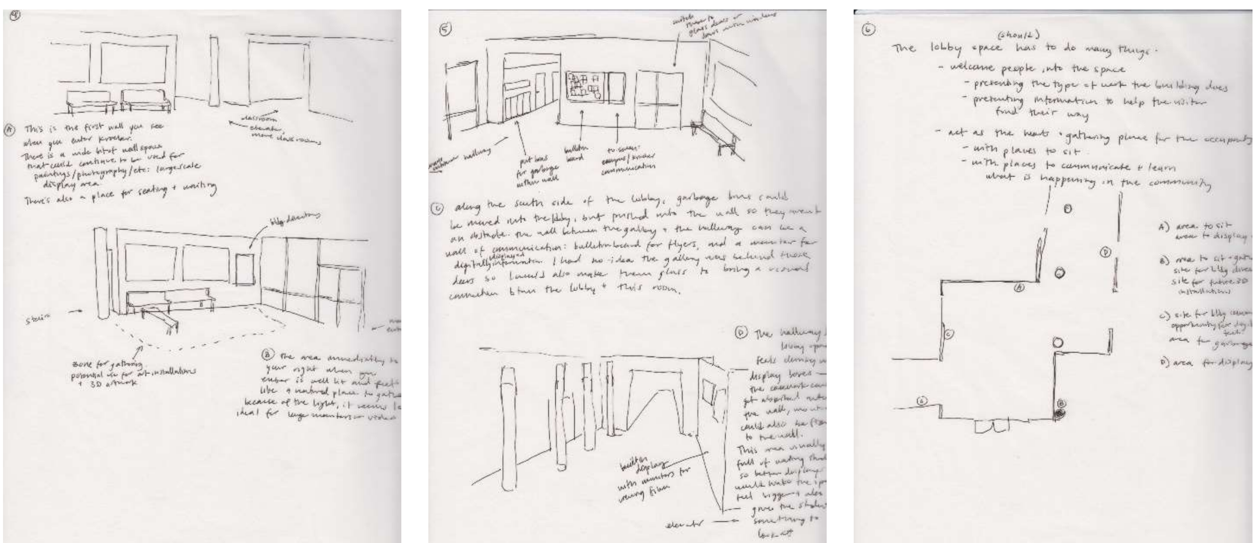


Figure 34 Perspective studies for the design development (left, center). Key plan summarizing proposals in developed in perspective by locating them on the plan (right)

Wurster HIS – 1 (WH1)

Note: Participant chose to work standing up.

There are a couple of things unresolved, but I don’t think I have a solution for them at the moment. It will need more thinking and maybe even restarting.

Figure 35 Designer at work in the HIS. All subsequent captures of work in the HIS will be of the design as seen in the cylindrical projection.

The student groups area – I think that has something in it. This area [points to the area under the staircase (figure below, left)], because of the double height and the staircase coming down. I think it is a nice area for the students to get together. But I remove the table from there. I don't think it works too well. But it has to be defined, maybe with a floor surface. And that niche also works well for the information board. I think that's the perfect place to move that thing [points behind him to the existing information board]. Maybe use proper lighting because its dark over there. That will also make this pop out, if it is lighted nicer. I didn't draw that [the lighting].

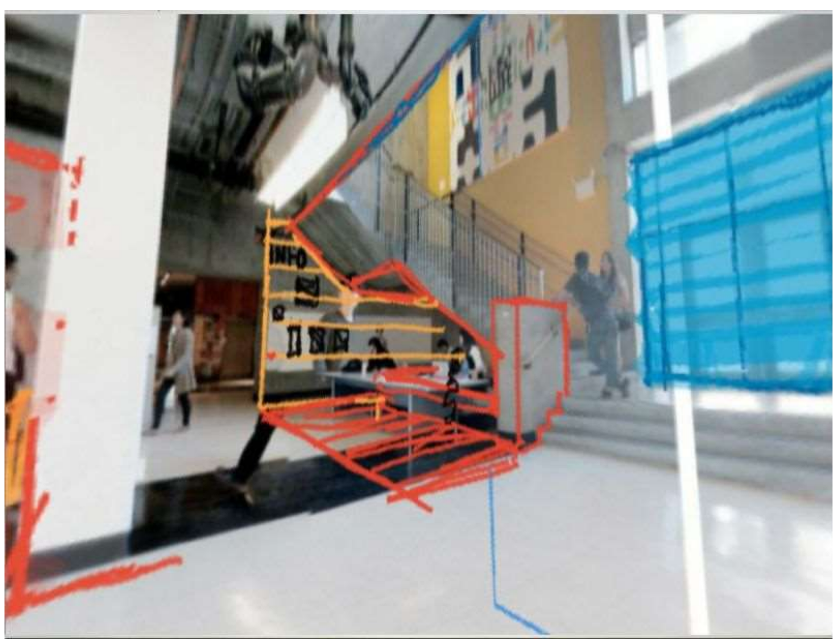


Figure 36 The student groups area

These two (figure below, left, right) complement each other with the overall elevated concept. Maybe this [below, right] is not elevated, I don't know, with the problem of that access over there. But this [below, left] can be elevated. This is more like a cozy area – these two (points to the two seating areas in yellow which frame the entrance, below, left) with the lowered ceilings and these hanging things, which are also acoustically functional. Those chairs are more like couches, softer. Here (below, right), that's a stand-up cocktail-like place, almost. I thought of a forest of columns, almost sculptural thing. When nobody's there it looks like an installation. When people are there, they can put their notebooks there, rest their elbows there, or their food and drink there, etc. You could have receptions there outside the big auditorium.

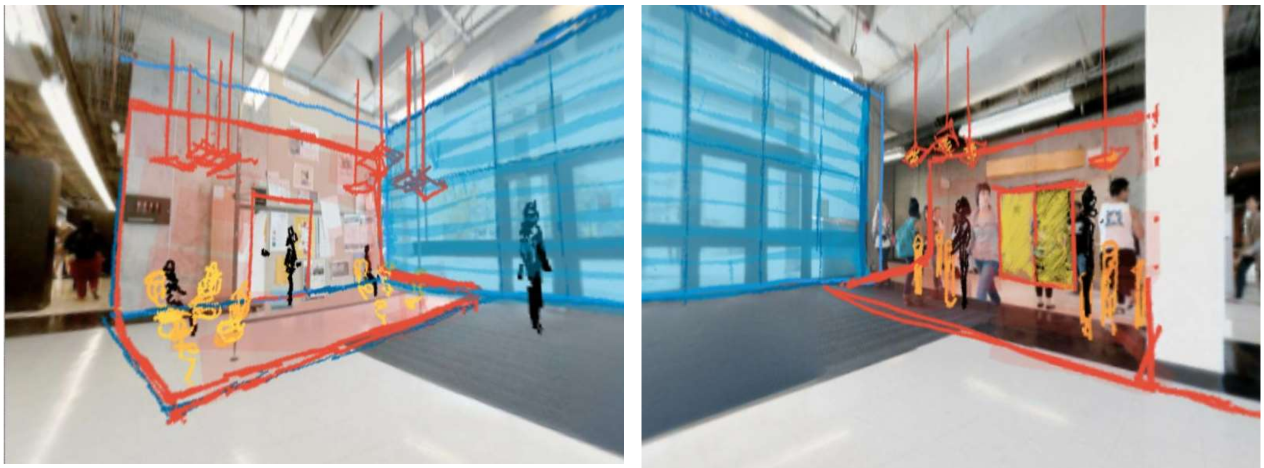


Figure 37 Complementary interventions

I don't think the trash should be in the lobby. I mean, there should be some bins in the lobby, but I think that's more of an industrial design problem, than an architectural problem, because they have to be movable. The obvious location is behind this column here (points to column in picture (above, right), or in front of this column, because that column is in the center of circulation, people move that way and that way (shows directions of movement). But one needs to design a trash bin on a different scale than this. Trying to deal with it at architectural scale is stealing away from the architecture rather than contributing to it. It can be a separate problem. It's like cars and buildings. We don't think of designing cars as a part of designing the building. I think have to be standalone. Hiding the bins would be an option, but I don't think that would be functional. I mean you could hide the trash bins somewhere, but I think it has to be outside and it has to be visible. Maybe it's better if they are so different from everything else that they strike out.

I think we are missing the core which I can't really touch. Maybe that's why I was focusing on these quarters (points to the three interventions), like that. If I was looking at it with a bird's eye view, maybe it would be more possible. I tried to see how things align. So, for instance, I tried to see how this column is aligned with (turns around are refers to the opposite wall) with this wall. It's not aligned with this wall is it? I can't tell that from here. Logically, this should be aligned with the wall, but I don't know, maybe it's not. It could be because of my perspective (refers to the perspective used in the design interventions).

I'm not happy about the continuity between that and this (yellow installation on the left and red installation on the right below). One should take the language of the other. But if you work three more hours on the same thing you'll get more continuity.

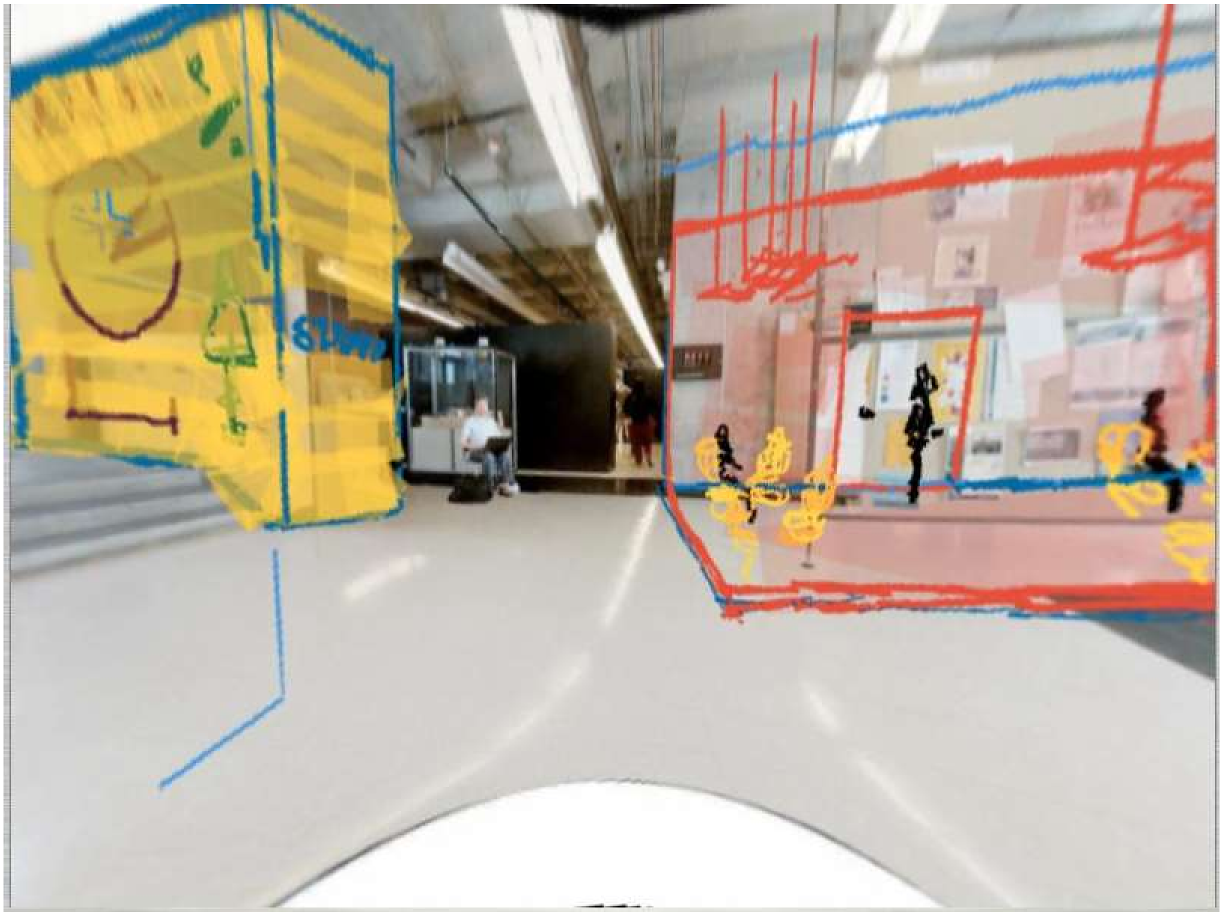


Figure 38 A discontinuity in design which the designer finds unsatisfactory

Wurster HIS – 2 (WH2)

Note: Participant chose to work in a sitting position. This meant that instead of turning the tablet to turn in the site, the participant used the feature which allowed the background image to be rotate to turn in the site while sitting. The blackboard was also used.

I'm thinking about a lot of video projection and a lot of digital interaction. On the main floor, below us here, on the ground, there's this big video projection and it has to be interactive, so if you step on something, or if you touch something, things move. So, you can play little games which are educational and somewhat fun. There are some sitting areas, some couches so people can sit. It has to be colorful, because everything is somewhat depressing, or a little too serious, so I put a lot of colors. These are people sitting on chairs (points to figures in black, below, center, right). I keep the location of the board (below, left), but I use a transparent material, so you don't block the view. And maybe that board has more facts and people can comment on opinions and interact digitally. I also draw some plants that will be placed everywhere (in green, below).

Figure 39 Central video projection area (demarcated by the yellow boundary) and seating (in black)

And there (above, right, below the staircase), before it was a poster or something, but even there it will a video projection. I feel like the video projection is better in that it doesn't take up space and you can change what it says any time. Below the staircase is a couch. It's also more colorful and brighter than it was before.

So that's my main theme. Have greener, more colorful ambience and the video projection. I'm not making any big structural changes, but I feel like the character of the space needs to change. It needs to be less austere. If I continued to work on this, I would just keep working until there was no more space for me to draw. But that's the main theme. I don't want to make huge changes, put panels or installations. I think the space is not that big. And people do walk around a lot and you don't want to intervene too much with that.

Wurster HIS – 3 (WH3)

The space is not alive enough. I don't know if I'm using the right terminology, maybe some colors or motifs on the walls and windows are required. The cafeteria entrance should not be hidden behind the board. Some I remove the board entirely and replace it in part with this circular board here (bottom left). I don't want it to be placed precisely in the center of the space, but to be closer to the main door than the staircase. By wrapping it around in a cylinder, it looks less visually imposing. I also added a sculpture in the central space, again, not in the center, but closer to the staircase than to the main entrance.

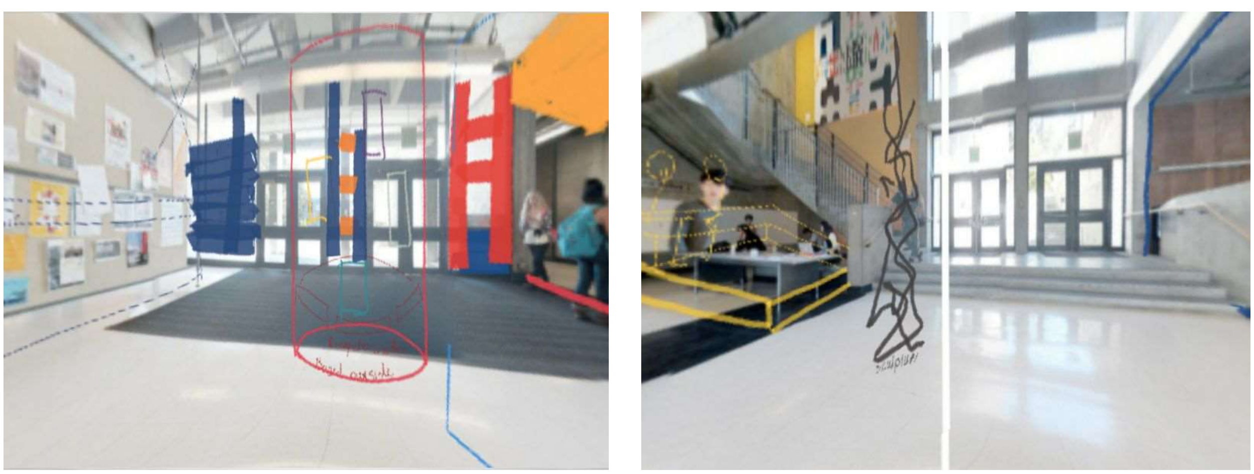


Figure 40 General views of proposal

Here and here (below left, below middle) we can have spaces for teamwork or something like that. The space is not impressive enough for being a lobby of an architecture department. That was my general impression of the space. There should be some re-organization in the space.

This (main entrance) and this (entrance to the auditorium) are two big entrance areas, and so I felt they should be visually demarcated in some way.

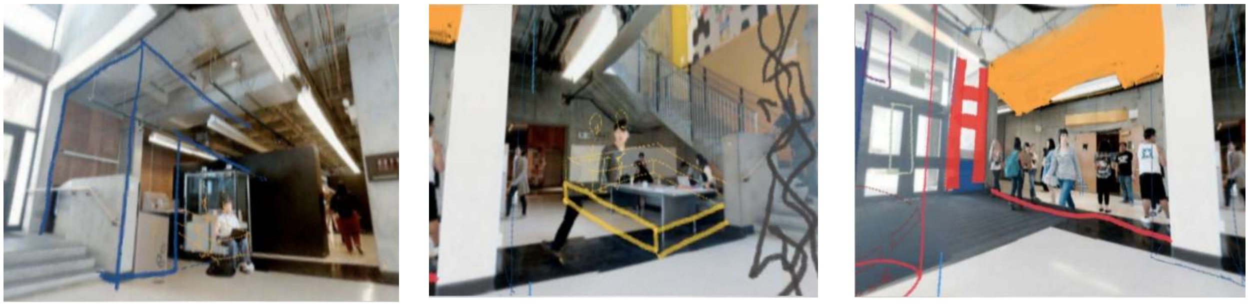


Figure 41 'teamwork areas' (left, middle); separation between two big entrances

From this picture of the site, it doesn't look impressive enough, so my interventions are focused on this aspect of the problem. I did not address all the detail in the brief in the time available, but I felt this was the one big issue.

Wurster HIS – 4 (WH4) (H)

(Begins with some brief notes about the media)

Not being able to see the plan view and the section view, and so, not being able to see how this space connects to neighboring spaces felt like a constraint. And I also don't have a site plan, and now I'm beginning to feel this constraint, so that's where I decided to stop. I don't have an idea right now but may be another day I could erase some of this and work on a new scheme. But it has been quite a fluent process. I didn't get bored, I didn't get frustrated by the UI. The time seemed to pass very quickly. From here, if I wanted to communicate something, maybe I'd start color coding. This is like a napkin sketch. Once you have this, and then someone gives you a plan of the whole building, then I would move to a different media.

First, I tried to familiarize myself with the space and after you told me the basic functions of the different areas I started thinking about the goals and the east-west axis. So, once I established that the east-west axis is the major circulation axis, I thought the space could use a bit of definition. That's why I started playing with ceiling treatments, maybe opening up these walls, like, taking spaces where people naturally collect and giving them a bit of definition and character or some kind of enclosure. It's hard to tell how the ceiling is treated. It looks like it's just the exposed concrete structure and then the lights are suspended. I thought that maybe a drop ceiling over the entrance and a drop ceiling over the naturally occurring breakout spaces.

And then my scheme with the elements in the center, that was the first thought. People circulating in both directions. They would necessarily have to go through there (the center) and be forced to look at something (information) maybe? And then I considered an alternative scheme which I ended up with, which involved voiding the center, and letting people look at stuff as they circulate across the east-west axis. So, if I gave them something here, they would be forced to look at it as they pass by. So, this was the main starting point.

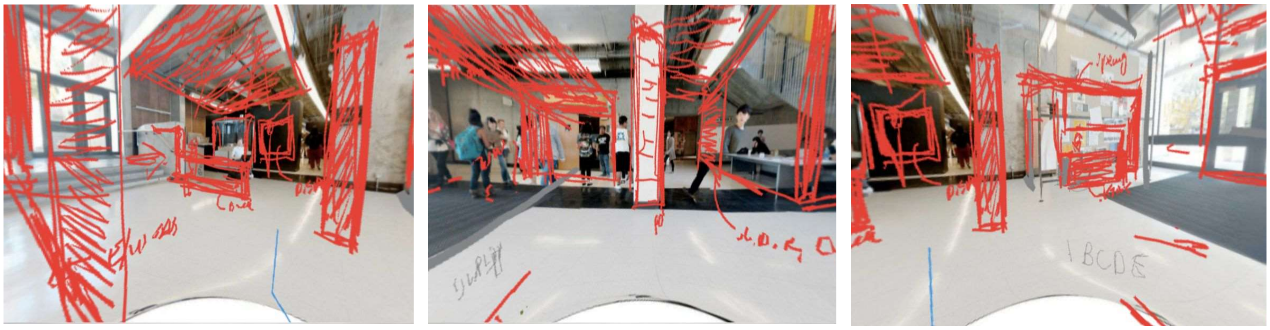


Figure 42 Giving definition to breakout spaces through the use of drop ceilings and other devices

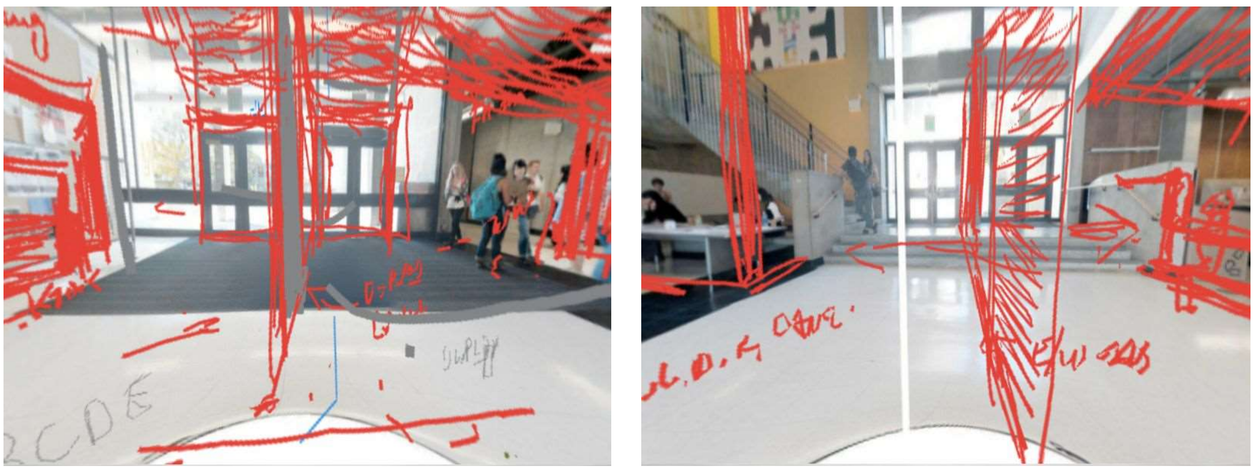


Figure 43 Giving definition to the E-W axis but voiding the center. Using the built parts to show information.