SEEING AS AESTHETIC EXPERIENCE AND CREATIVE ACTION: VISUAL PRACTICES WITH SHAPE GRAMMARS IN DESIGN EDUCATION

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Abstract

In the discussion of what makes a "creative" or "imaginative" design, rational concerns have come to override what we might call the "aesthetic experience" – that is, an experience in which all the senses are highly engaged, not only the mind. It has become unpopular and perhaps even politically incorrect to talk about what we feel, like, or respond to viscerally – discussions of emotion, pleasure, or delight are often seen as too subjective, qualitative or illogical, influenced by personal preference and cultural bias. This stems mainly from the age-old arguments positing a mind-body split that gives value to what is seen as "intellectual" over what is seen as personal, idiosyncratic, unquantifiable; and "normalized" over what is seen as ambiguous, peculiar, outlying.

This situation presents an enormous problem for design students. They may be told that their design needs improvement, but they do not really know the why or what's next, nor do they know how to remedy the problem. Students need tools to help them reflect on their design, advance it, interact with it, change it, then interact with the change. While modern technology has provided us with the means to cut down on laborious, energy-draining tasks of drawing and re-drawing, it has perhaps inadvertently over-simplified the design process. We have lost the steps where discovery can take place – the computer does them for us.

In this dissertation, I propose one way to address the current state of the problem – especially in the hands-on practice-based design studio and project-based design courses – by employing the principles of shape grammar theory. The use of shape grammars in design education can help students grow as designers and put them back in touch with their unique and instantaneous responses to emerging designs; in other words, shape grammars can help students "feel their way" toward better designs by providing them with a set of actions that can be applied. Shape grammar rules and schemas provide students with steps, a creative framework to follow and execute, which can guide them to generate and improve their designs, while developing their aesthetic and sensory-perceptual creative understanding and insight.

Thesis Supervisor: George Stiny
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"There is something I don't know
    that I am supposed to know.
I don't know *what* it is I don't know,
    and yet am supposed to know,
And I feel I look stupid
    if I seem both not to know it
            and not know *what* it is I don't know.
Therefore, I pretend I know it.
    This is nerve-racking
    since I don't know what I must pretend to know.
Therefore I pretend to know everything.

I feel you know what I am supposed to know
but you can't tell me what it is
because you don't know that I don't know what it is.

You may know what I don't know, but not
    that I don't know it,
and I can't tell you. So you will have to tell me everything."

--R.D. Laing[1]

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[1] Laing, Ronald David. *Knots.* Ringwood, California: Penguin, 1971.

1 Introduction

In many architecture and planning schools, design education continues to depend on the traditional studio milieu as formulated by the academicians of the eighteenth century French École des Beaux-Arts. Since the Renaissance workshop, the studio class has been a place where students practice drawing, painting, and sculpture; do hands-on projects; create new art and designs; and develop themselves under the guidance of studio mentors. However, the social and technological changes brought about by the Industrial Revolution challenged both the Renaissance view of the artist as genius and the eighteenth century Romantic view of the artist as independent eccentric, in turn affecting how artists and designers would be educated. With the emerging demands of growing industrial societies in Europe and in the United States, specialized programs increasingly became necessary. Studio education has developed widely nuanced teaching styles in a seemingly standardized educational environment. While studio education continues to maintain roots in classical studies as in fine arts, it also gets informed by artisanal handicrafts, the Arts and Crafts and industrial design as in applied arts.[2]

Even though designerly discussions in the studio have always dealt with classical Vitruvian values – *utilitas (function), firmitas (structure), venustas (delight)*[3] – with the modernist quest for efficiency and optimization in the beginning of the twentieth century, Vitruvian values that are easier to talk about, such as those dealing with functional and structural matters, have been highlighted, whereas the values that are not as straightforwardly addressable, such as those of aesthetics, have often been obscured or devalued in the conversation. Issues concerning function and utility have been habitually championed over those that seemed difficult to formulate. Aesthetic and experiential exploration has been generally seen as developing as a consequence of these other considerations, or mere ornamentation or decoration.[4] Shape, form and material have been considered merely obedient to abstract and rational ideas. Turning spatial and architectural experience into stories, purely formal and visual (non-verbal) stories were sacrificed for the sake of verbal, logical and social stories.[5] All these factors have contributed to the demise of concern for delight. This problem prevails in the current design studio.

In the discussion of what makes a "creative" or "imaginative" design, I claim rational concerns have come to override what we might call the "aesthetic experience" – that is, an experience in which all

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[2] Among many valuable resources, for comprehensive overviews on the teaching of art and design, see: Bell, Quentin. *The Schools of Design.* London: Routledge and Kegan Paul, 1970. Also see: Efland, Arthur D. *A History of Art Education: Intellectual and Social Currents in Teaching the Visual Arts.* New York: Teachers College Press, 1990. Macdonald, Stuart. *The History and Philosophy of Art Education.* James Clarke & Co., 2004. [1970.] Romans, Mervyn (Ed.). *Histories of Art and Design Education: Collected Essays.* (Readings in Art and Design Education Series. Series Editor: John Steers.) Bristol; Portland, Oregon: Intellect Books, 2005. Ockman, Joan (Ed.). *Architecture School: Three Centuries of Educating Architects in North America.* With Rebecca Williams (Research Editor). Cambridge, Mass.; Washington D.C.: The MIT Press; Association of Collegiate Schools of Architecture, 2012.

[3] Vitruvius. *Ten Books on Architecture.* Edited by Ingrid D. Rowland and Thomas Noble Howe. Cambridge; New York: Cambridge University Press, 1999.

[4] Crane, Walter. *The Claims of Decorative Art.* London: Lawrence and Bullen, 1892.

[5] Mitrovic offers a telling account of a guest speaker "critic" outwardly dismissing visual and formal explorations in the opening of an exhibit, but also includes the revival of theories of pure form in current philosophical aesthetics and philosophy of art, such as that offered by Nick Zangwill. See: Mitrovic, Branko. *Visuality for Architects: Architectural Creativity and Modern Theories of Perception and Imagination.* Charlottesville: University of Virginia Press, 2013.

the senses are highly engaged, not only the mind.[6] It has become unpopular and perhaps even politically incorrect to talk about what we feel, like, or respond to viscerally – discussions of emotion, pleasure, or delight are often seen as too subjective, qualitative or illogical, influenced by personal preference and cultural bias. This stems mainly from the age-old arguments positing a mind-body split that gives value to what is seen as "intellectual" over what is seen as personal, idiosyncratic, unquantifiable; and "normalized" over what is seen as ambiguous, peculiar, outlying. This core dichotomy was accompanied by many others in human affairs: objectivity or subjectivity, rationalism or empiricism, normativity or plurality, and so on.

This situation presents an enormous problem for design students in the current design studio. They may be told that their design needs improvement, but they do not really know why, nor do they know how to remedy the problem. When it comes to aesthetic and sensory-perceptual creative understanding in assessing their designs, as in R. D. Laing's poem in *Knots* (1971), it becomes nerve-racking for students to try to comprehend the why and what's next. Students need both tools and teachers to help them reflect on their design, advance it, interact with it, change it, then interact with the change. While modern technology has provided us with the means to cut down on laborious, energy-draining tasks of drawing and re-drawing, it has perhaps inadvertently over-simplified the design process. We have lost the steps where discovery can take place – the computer does them for us. The computer's agency becomes especially problematic when every creative design step is systemically mediated by the combinatorial digital logic, and when the computer is prematurely incorporated into the educational realm without firstly addressing the formal structures operating digital thinking and digital machines.

In this dissertation, I propose one way to address the current state of the problem – especially in the hands-on practice-based design studio and project-based design courses – by employing the principles of *shape grammar theory*.[7] The use of shape grammars in design education can help students grow as designers and put them back in touch with their unique and instantaneous responses to emerging designs; in other words, shape grammars can help students "feel their way" toward better designs by providing them with a set of actions that can be applied. Shape grammar rules and schemas provide students with steps, a creative framework to follow and execute, which can guide them to generate and improve their designs.

With shape grammar pedagogy, I highlight *aesthetic experience* – especially its sensory-perceptual and intellectual components – and render it palpable. Using the explicitness provided by shape grammars to ensure aesthetic and sensory perceptual engagement, I aim to see what valuable steps do not become lost when they are delegated to the computer. This vital feature provides the missing link in the "language" and "logic" of current design studio conversations, not only by making

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[6] Aesthetic experience is intrinsically manifold and intertwined, entailing various sensory-perceptual, intellectual and emotional capacities. As further elaborated in Chapter 2, I specifically focus on the two primary components of aesthetic experience in this dissertation: on the "seeing" component – visual engagement – and on the conceptual tools – intellectual engagement – that are specifically related to seeing. In this framework, I also focus on creative visual design as a component of human creativity.

[7] Stiny, George and James Gips. "Shape Grammars and the Generative Specification of Painting and Sculpture." Petrocelli, O. R. (Ed.) *The Best Computer Papers of 1971*. Auerbach, Philadelphia, 1972. pp. 125 – 135. Also see: Stiny, George. *Shape: Talking about Seeing and Doing*. Cambridge, Mass.: The MIT Press, 2006.

aesthetic and sensory-perceptual education apparent in the creative process, but also by emphasizing them as central components within creative design education.

Students and instructors in the current design studio may often optimistically anticipate that discussions about aesthetic experience, its objects, forms, creation, reception and methods will spontaneously find their place in the critiques and directed conversations. The pedagogical promise of the design studio for cultivating design innovation, imagination and originality are expected to materialize and be commented upon in these exchanges between *the apprentice* and *the master* – the learner and the instructor. However, continual externalization of ideas engendered in the conversational milieu of the studio is often not enough to ensure that concerns around aesthetics, aesthetic experience and artistic and designerly form are addressed.

In fact, in the overly cognitive mindset of the studio, an explicit discourse on aesthetic engagement is systematically avoided or altogether lacking. We have lost interest, motivation, meaning or the means to have deep aesthetics-based and form-based conversations in design education. We have forgotten the excitement of pure delight, contemplation of shape and form, and the foundational value of sensory-perception in creativity, imagination and originality. As Sir Ken Robinson observes, we "systematically" and "routinely" destroy the capacity of human imagination and aesthetic experience "in our children and in ourselves" through education. We are being *anaesthetized* and *deadened* as we are schooled, even in design schools:

> The arts especially address the idea of aesthetic experience. An 'aesthetic experience' is one in which your senses are operating at their peak. When you are present in the current moment. When you are resonating with excitement of this thing that you are experiencing. When you are fully alive. An 'anaesthetic' is when you shut your senses off and deaden yourself to what's happening. [...] We are getting children through education by anaesthetizing them. And I think we should be doing the exact opposite. We should not be putting them to sleep, we should be waking them up to what they have inside themselves.[8]

Answering this call in the context of design education, conversations and *self-conversations* on aesthetic experiential and sensory-perceptual engagement need to be systematically and actively facilitated by instructors. We cannot rely on the spontaneity of studio critiques, veiled criticisms or vague conversations currently present in the design studio to introduce these important design concerns. The "sensory-perceptual" and the "aesthetic experiential" should methodically be presented as one of the core values that brings in the idiosyncratic as opposed to the normative, descriptive as opposed to prescriptive, sensory-perceptually emergent as opposed to cognitively fixed. Shape grammar theory and formalism have repeatedly shown us the fundamental significance of aesthetic experience and sensory-perceptual engagement in visual design.[9] For this reason, shape grammars and shape grammar

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[8] Robinson, Sir Ken. "Changing Paradigms." Lecture delivered at *the Royal Society for the encouragement of Arts, Manufactures and Commerce* (RSA), London. 16th June 2008. Reached at the official website of the RSA: https://www.thersa.org/

[9] Stiny, George. *Shape: Talking about Seeing and Doing.* Cambridge, Mass.: The MIT Press, 2006. On visual rules and schemas, see: Stiny, George. "What Rule(s) Should I Use?" *Nexus Network Journal* 13.1 (2011): 15-47. Also see: Stiny, George. "The Critic as Artist: Oscar Wilde's Prolegomena to Shape Grammars." *Nexus Network Journal* 17.3 (2015): 723-758.

inspired methods can effectively guide design studio curricula and enable us to have these conversations in a systematic manner. Design exercises in *The Foundations* and elsewhere can be structured in order to highlight delight as well as the other design values.

Like shape grammars, I take visual art and design as *computational* undertakings. I use the theory and methods of shape grammars as the computational framework to guide artists and designers in exploring their creative processes, reasoning, and design solutions. This is especially useful for beginner designers. In this dissertation, I focus on creative design especially in its *visual*, *graphical*, *pictorial*, *formal* and *spatial* compositions: namely, the aspects of design elements that emerge from seeing, exploring visuals and graphics, drawing, picture-making, delving into designerly shape, form and space. Although other sensory-perceptual events such as music can be studied in computational frameworks, I focus on the *visual creative design* that is often situated at the foundation of design education.

In this undertaking, "visual shape rules" and "transformations" lie at the heart of the creative process and offer step-by-step executable procedures to designers. Design processes can be explained in the form of *shape computations*, generated by sets of visual shape rules. Shape rules are basic operations that are based on *seeing* and *doing*, and which describe a singular step of the step-by-step progression of design. Shape rules have a particular format, but specific rules are not provided to designers from the outside; they are dynamically generated by the designers themselves during their individual creative activities, which in turn allow maintaining running or retrospective records of them. Designers can write, add, drop and change the rules – on the go and *in situ*.[10]

In addition to being able to generatively create designs, shape grammars systematically highlight sensory-perception, aesthetic experience and the phenomenology and psychology of perception with notions like *embedding*, *ambiguity* and *pluralism*.[11] These notions together emphasize the unrestricted and unstable ways that we *see* shapes and forms. Rules help designers to momentarily capture them in an ongoing, open-ended, visual design process. The subjective and pragmatic nature of embedding ensures that our unique ways of seeing are not lost. Moreover, they come to hold central importance for our creativity and imagination. The computational model of creation formalized by shape grammars is neither deadening nor unengaging in aesthetic experience. On the contrary, the computational model helps us go much deeper into that experience.

1.1 Content

This thesis examines the visual practices in seeing, embedding, doing, applying visual rules and visual schemas as conceptual tools with which to guide students in cultivating their sensory-perceptual and aesthetic experiential skills in visual design. It first provides an overview of issues in aesthetics and the philosophy of art, and examines efforts of relevant theorists and educators who developed design exercises that highlight sensory-perception and aesthetic experience. The thesis also provides relevant

[10] In this computational design process, we can record our precise procedures in the form of rules and computations or have the already-created rules work for us in an automated manner in generating new designs. For such goals, shape grammars offer rigorous comprehensive formalism to describe shapes and shape computations. Although shape grammars can deliver mechanical and automated processes, shape grammars treat these processes as special cases of open-ended and indeterministic processes of creation. The amount of control and detail in the production system can be adjusted by the grammar's author.

[11] Stiny, George. *Shape: Talking about Seeing and Doing*. Cambridge, Mass.: The MIT Press, 2006.

theoretical accounts of issues today in aesthetics, criticism, philosophy, psychology, and education in order to better contextualize some of the discussions. It then analyzes the possible applications of shape grammars or shape-grammar inspired methods to design exercises in order to externalize and explicate sensory-perception, aesthetic experience, aesthetic objects and aesthetic evocations in the current design studio.

In Chapter 2, I argue that understanding and teaching *visual design as computation* can revive and educate creativity in visual design by facilitating open seeing, "reasoning," appreciation for ambiguity (flexibility and changeability) and aesthetic experience. I trace the pedagogies of visual design computation in four core domains: a) visual design as aesthetics, b) visual design as language, c) visual design as science, and d) visual design as computation. In this chronological timeline, I particularly investigate theories of vision and visual practices, from objectivist models to pragmatist ones. Following from the various understandings of design, I present a number of dialectics in an effort to continue the rigorous yet fluid pedagogical vision offered by the design computational paradigm and shape grammar theory.

In Chapter 3, I present shape grammar theory and its unique, rigorous methodology, which directly deals with sensory-perception and visual reasoning in personal and educational settings. I particularly formulate shapes as aesthetic objects and our designerly creative interaction with shapes as aesthetic experience. I focus on ways of seeing in creative visual design, establishing design basics (fundamentals) as shapes, visual rules, visual schemas and visual computations. I begin to discuss progressive applications of seeing, embedding, visual rules and visual schemas in the creation of basic visual designs. I show visual computations and visual explorations that capture the precise and fuzzy creative design processes. I particularly focus on visual transformations and sums. I present a number of exemplary visual sequences utilizing visual schemas in the generation of basic visual designs.

After developing the first-hand design experiments, in Chapter 4, I introduce basic (fundamental) design exercises that develop heuristics, such as *"seeing fast and seeing slow," "seeing backward and seeing forward" and "seeing of and seeing for."* In the course of these exercises, I provide practical and methodical means for students for capturing their sensory-perceptions, aesthetic experiences and visual reasoning. I continue to build on the notions of seeing, embedding, visual rules and visual schemas, relating the progressively more intricate processes to previous exercises. This progression of exercises can inform the curriculum of two-semester courses on the topic in the future, as well as applications in the design studios. For this purpose, I also continue to elaborate on visual reasoning, seeing and doing: how our sensory-perceptual, aesthetic and experiential-pragmatic knowledge is developed through such design exercises, and how they lay at the foundation of our creativity.

Following the theoretical and historical investigation in Chapter 2, Chapter 3 and Chapter 4 include various illustrations and drawings. In supporting my theoretical and pedagogical arguments, I present evidence from personal visual sequences and visual computations, in addition to experimental results from workshops and classes that I ran independently, at the Massachusetts Institute of Technology (MIT), at the Singapore University of Technology and Design (SUTD) and at the Izmir Institute of Technology (IZTECH).

Finally, in Chapter 5, I conclude by elaborating on sensory-perceptual, aesthetic and experiential-pragmatic knowledge. I summarize my argument that students and educators can take shape grammar theory, formalism and pedagogy and apply it to their visual practices to improve their design skills and enhance their creativity. This program can add to, expand and transform existing studio practices, and re-introduce aesthetic experience and sensory-perception into the design studio curricula at architecture and design schools.

2 Delight in Distress: Reviving Aesthetic Experience in Creative Visual Design

The core value and objective of visual art and design education is to educate *creativity*, *creative sense* and *creative capacity*. Yet, the very definitions of creativity often remain elusive. What is creativity and what does it entail in visual art and design? And, how can being creative and producing interesting visual art and design be understood, learned and taught? What may a pedagogy of creative art and design look like, in personal practice, in the classroom or in the studio? In this chapter, I elaborate on these core questions and argue that understanding and teaching *design as computation* can revive and educate creativity in visual design by facilitating open seeing, "reasoning,"[12] appreciation for ambiguity (flexibility and changeability) and aesthetic experience.

Creativity in visual art and design is often understood as a mindset or state that involves a kind of agility, quickness, and flexibility in human understanding, thinking, sensing and feeling. Creative individuals can perceive the world in new and variable (unexpected) ways, explore and develop patterns, construct peculiar connections and present interesting outcomes. With expertise in their domain and medium, they can convey their ideas and insights in masterly ways. The powers of *observation* and *imagination* are often emphasized as driving forces in generating new ideas and insights. Among many human capacities, *genius*, *wit*, *fancy*, *association* or *imagination* are similarly discussed as determinants of creative capacity.[13] After the invention of *Romantic originality* as a key artistic notion, originality, uniqueness and innovation became hallmarks of creativity, although many have also disputed the possibility of *true* originality on artistic and philosophical grounds.[14] Philosopher of art Monroe

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[12] I consider "reasoning" and "thinking" as intertwined with sensation and perception, as studied in Gestalt psychology and by those design theorists who subscribe to Gestaltism. I follow their formulation that "all thinking is basically perceptual in nature" and that the dichotomies between sensing-perceiving and reasoning-thinking are false and deceptive. The notions of *visual reasoning* or *perceptual thinking* refer to these more specific modes of human sensation, experience and action. To clarify further, I do not use the notions "reasoning" and "thinking" as described by rationalism or cognitivism, which was to point at pure abstract reason, rationality or logic in the Cartesian sense. See: Arnheim, Rudolph. *Art and Visual Perception: A Psychology of the Visual Eye.* Berkeley: University of California Press, 1974 [1954]. Arnheim, Rudolph. *Visual Thinking.* Berkeley, Los Angeles, London: University of California Press, 1969.

[13] From the early Enlightenment to the development of modern psychology, intellectual or physiological human capacities were formulized in various formats to understand human sensing, thinking and creativity. Some of the notions that philosophers, early psychologists and physiological psychologists commonly theorized upon were wit, fancy, imagination, memory, observation, and association. John Locke (1632 – 1704) was among the many philosophers who theorized extensively on these notions: Locke, John. *An Essay Concerning Human Understanding.* John Locke; Edited with an Introduction, Critical Apparatus and Glossary by Peter H. Nidditch. Oxford: Clarendon Press, 1975. Also see: Addison, Joseph. *Selections from Addison's Papers Contributed to the Spectator.* Edited by T. Arnold. Oxford: Clarendon Press, 1886. Especially see Addison's (1672 – 1719) paper "The Various Kinds of Wit" in Spectator, No.62. In addition to these notions, ideas on a number of human capabilities were thought to enhance creativity, such as William Hazlitt's (1778 – 1830) "disinterested sympathy," which also inspired John Keats' (1795 – 1821) "negative capability": Hazlitt, William. *Selected Writings.* Edited with an Introduction and Notes by Jon Cook. Oxford; New York: Oxford University Press, 1998. This is an abbreviated version of a very rich list that indexes theories on many human capacities and capabilities.

[14] With the rise of Romanticism, the longstanding artistic virtues of mastery, classicism, canon, imitation, metaphor and allusion began to lose their value. Instead, it was seen as important to break with tradition and distance one's self from precursors, following one's personhood. Originality, invention and difference thus came to be associated with artistic and scientific creativity. As Jean-Jacques Rousseau famously exclaimed, "If I am not better than other men, at least I am different." Modernism's ties to Romanticism enlivened these quests in the

Beardsley (1915 – 1985), in his seminal book *Aesthetics from Classical Greece to the Present: A Short History* (1966), surveyed the intricate connections between *(a)* theories of creativity, *(b)* human capacities held responsible for its existence and cultivation, and *(c)* issues in art and aesthetics.

Creativity in art and design is commonly associated with the types of human capacities or modes that are "cognitive," "intellectual" or "conceptual" in nature, because of the pervasive mind-body dualism: Cartesianism and [fine] art's association with these purportedly "higher" modes of human consciousness. However, as thoroughly debated in the long-standing debate of rationalism versus associationism versus empiricism, creativity is essentially bound to human sensation and perception, as well.[15] In other words, in addition to those aspects that initially seem to speak predominantly to the human intellect, aspects that seem to speak to bodily feeling and the senses – senses of sight, hearing, smell, taste, touch, vestibular, proprioception and motor activity – are also pivotal to creative (visual) art and design. In other words, our very intelligence as sentient beings is not just in our heads, or hands, but permeates every move – and sign – of our sensory-motor presence (as in the notion of "Dasein".)

The immediate sensations that art or designs induce gradually in human sensation, perception and reasoning, constitute the experiential foundations for art and designs to be pondered and understood. When we look at paintings and sculptures, they directly engage our seeing; when we hear classical music or jazz, they directly engage our hearing; when we touch a crafted wooden table or walk in an architectural space, they directly engage our tactile and kinesthetic senses. When we make or craft artifacts, our motor responses and activities also fashion our active and direct engagement. Artistic and designerly creativity, therefore, requires proficiency in articulating or bridging human sensation, perception and cognition. It asks of artists and designers adept command and control over the creation of human sensations, sensory-perceptual experiences and episodes, which they orchestrate through their art and designs, and which art and designs evoke in the spectator, observer or viewer.[16]

Along with the evocation of feeling in the form of sensory-perceptions and cognition, evocation of feeling in the form of emotion also plays a central role for creativity in art and design. In this dissertation, I am not going to venture into the issues regarding the depiction, expression and representation of human emotion in visual art and design *per se*, often thought of as emotional "moods" or "meanings," such as sadness, pity, joy, fear, happiness or affection. Instead, I simply subscribe to William James's (1842 – 1910) pragmatist notion that without feeling, emotion, a sense of "practicality" or "interest," human beings would not be able to regulate their discernments, likes, dislikes, preferences

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twentieth century. See: Waterhouse, Francis A. "Romantic 'Originality.'" *The Sewanee Review* 34.1 (Jan., 1926): 40 – 49.

[15] Tuan, Yi-Fu. *Space and Place: The Perspective of Experience*. Minneapolis: University of Minnesota Press, 1977.

[16] Although we may think that specific arts target or evoke only specific senses, as Edith Ackermann puts it, "synesthesia matters!" In fact, we always sense through multiple sensory channels and media. She adds, a painting can "move" us beyond vision; we can be "touched" by music. Or, we can be "caressed" by the smell of blossoms, as Johann Wolfgang von Goethe put it, "the hands want to see, the eyes want to caress." As Juhani Pallasmaa highlights, the skin has eyes, the hand thinks and experience always comes in experientially holistic and embodied forms. (Conversations with Edith Ackermann, 2015 – 2016. Massachusetts Institute of Technology, Cambridge, MA.) Furthermore, we usually explore and understand through "acting and handling rather than by mere contemplation" (Arnheim, 1969: vii); therefore action, manipulation and motion matter, too. However, for the sake of simplicity, we focus on *visual* kinds of experience in art and design in this dissertation.

and reasonings.[17] In other words, left purely with sensory-perception and the intellect, we would not be able to act "sensitively," make "meaning" or "truth."[18] What we think of as being purely rational is indeed laden with emotional and practical content. In a way, visual art and design at once precedes and transcends human sensation and rationality.[19]

In addition to the expressive qualities of artworks and designs that evoke feelings and emotions – likes and dislikes – it is my purpose, in this thesis, to better understand the nature and the significance of so-called "aesthetic experience" – a term as illusive and poorly understood as "creativity" itself. What does aesthetics and aesthetic experience entail in visual art and design? I define aesthetics and aesthetic experience in *sensory-perceptual, phenomenological* and *experiential-pragmatic* terms: an aesthetic experience is in nature *aesthetic*, if the aesthetic response is: *(a)* strongly related to sensation, perception, and emotion, *(b) phenomenological* – aesthetic experience lies in the meeting of the aesthetic object, the intentional object and the aesthetic recipient, and *(c) experiential-pragmatic* – when aesthetic objects and the subject are engaged, experience unfolds in space and time (spatio-temporal mode) based on the object's affordances and recipient's fleeting interests.

I further define aesthetics as how things *look* and how they are *seen* as part of the *human sensorium*, because how things look and are seen – in the phenomenological relation – indeed give me insight into how things *are*. The appearance of a design and its structure – the ways it is put together, configured or composed – are integral. Appearances are not independent of structures; structures are not independent of appearances. Yet, appearances and structures are established only temporarily, within the bounds of an aesthetic experiential and *aesthetic actionable* process.[20] In different aesthetic experiential processes, between the same object and the same recipient, appearances and structures may be significantly diverse. Based on different appearances and structures, I can take different actions. Moreover, based on the actions that I take, I may alter yet again appearance and structure. This dynamism and plurality, I recognize, is indeed one of the core determinants of creativity.

Unlike classical definitions that allude to an absolute objective or idealistic reality manifesting as beauty in our mortal world, I subscribe to theories of aesthetics – especially those that speak to empiricism and pragmatism – which do not seek absolute statements for the definitions of beauty, but seek to understand the nature of a highly subjective, phenomenological, ephemeral, pluralistic and potentially incoherent experience. I also argue that aesthetic experience and action – like any human experience – is connected to human sensation and perception, human emotion and feeling, and human reasoning and rationality. Within this framework, I trace the potentials for creative art and design education through the education of aesthetic sensation, sensibility, discernment, judgment and appreciation. The production of beautiful and delightful things is strongly connected to the artists' and designers' cultivated sensation, sensibility, discernment, judgment and appreciation, as well as skilled creation of the beauty, harmony and delight of *shape and form*.

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[17] I use the terms "emotional" and "practical" in the same manner as the American pragmatist philosophers and as employed in William James's psychology. See: James, William. *The Principles of Psychology*. Cambridge, Mass.: Harvard University Press, 1981 [1890].

[18] James seemed to agree with John Keats (1795 – 1821) and others who argued for this equation, and the concise teaching of it: "Beauty is truth, truth beauty – that is all ye know on earth, and all ye need to know." Keats, John. "Ode on a Grecian Urn." Quiller-Couch, Arthur. (Ed.) *The Oxford Book of English Verse: 1250–1900*. 1919.

[19] James succinctly clarifies the pragmatic motto: "Every way of classifying a thing is but a way of handling it for some particular purpose."

[20] I offer the term "aesthetic actionable" as a potential action prompted and afforded by my aesthetic experience.

Research in various fields suggests that creativity can be investigated through four different lenses: *a)* the creative process, *b)* the creative product, *c)* the creative individual or group, and *d)* the creative environment.[21] In our theoretical framework, we similarly talk about design as a process that is by nature creative and that involves the analogous four key domains: *a)* the design process or design activity, *b)* the design product, design output, design solution, or simply a "design", *c)* the designer, designers or design team, and *d)* the design environment or design setting. In the context of this dissertation, these groupings can help us describe visual art and design – "creative" processes rather than products – with a focus on the individual designer's creative drifting and on-the-fly "reasoning" during the design process and design experimentation in their humble laboratory.[22]

Design products, outputs or solutions are taken as the products of creative processes that appear once the process (by nature continuous) concludes, is looked at after-the-fact, and discretized. Design products are not treated as ends or goals in themselves, but rather as place holders or halts in time, when things temporarily fall into place – only to be re-placed and re-arranged later. The design environment is assumed as the interactions of designers with their materials, products and processes. The social facets of creative design are taken specifically in the context of design education, particularly how students talk about their processes and products, how instructors guide them in their processes, how feedback and criticism is constructed and provided.

In short, I define *creative design* simply as the dynamic and interweaved processes of *1)* how we put together *parts* in order to obtain *wholes;* and *2)* how we look at things to see *wholes* and *parts* and *structures.*[23] I specifically focus on how visual, graphical and spatial elements are generated, arranged and seen on a graphical and spatial canvas. In this effort, theories on visual organization, visual perception, and the psychology of perceptual "Gestalts" may serve as fundamental resources.[24] However, I subscribe

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[21] Howard, Thomas J., Stephen J. Culley, and Elies Dekoninck. "Describing the Creative Design Process by the Integration of Engineering Design and Cognitive Psychology Literature." *Design Studies* 29.2 (2008): 160-180.

[22] Pencil and paper can offer us a humble yet very sufficient laboratory for design experimentation. Stiny, George. "Introduction to Shape Grammars" course at the Department of Architecture, Massachusetts Institute of Technology. Fall, 2015.

[23] The part-whole theory is a culmination of theories that investigate the relationship of *parts* to *wholes,* or *wholes* to *parts.* In other words, the theory elaborates on various interesting questions that arise as to how parts of a thing are related to each other and how they are related to the whole thing. *Mereosis,* the relationship between parts and wholes, held a central role in the advancement of mathematics and led to the foundation of set theory and the modern field of mereology. The philosophy of part-whole is a fundamental epistemological and ontological question in our descriptions and understanding of the cosmos, including our theories of the body, mind and their existence in relation to the cosmos.

[24] Wertheimer, Max. *Productive Thinking.* New York: Harper, 1959. Also see: Wertheimer, Max. *On Perceived Motion and Figural Organization.* Edited by Lothar Spillmann; with contributions by Michael Wertheimer. Cambridge, Mass. : MIT Press, 2012. On principles, see: Koffka, Kurt. *Principles of Gestalt Psychology.* New York: Harcourt, Brace and Company, 1935. Also see: Köhler, Wolfgang. *Gestalt Psychology.* New York: H. Liveright, 1929. And: Köhler, Wolfgang. *Gestalt Psychology: An Introduction to New Concepts in Modern Psychology.* New York: Liveright Pub. Corp., 1947. On the advancement of Gestaltism and its influence on modern design schools, see: Galison, Peter. "Aufbau/Bauhaus: Logical Positivism and Architectural Modernism." *Critical Inquiry* 16.4 (1990): 709-52. Stable URL: http://www.jstor.org/stable/1343765. Also see: Jarzombek, Mark. *The Psychologizing of Modernity: Art, Architecture, and History.* Cambridge, U.K. ; New York: Cambridge University Press, 2000. I would like to offer sincere thanks to Michael Stern and Frederick Stern, Ph.D. on informing me on Catherine Stern and Margaret B. Stern's significant contributions in mathematics education in the twentieth century, which were inspired by initially Montessorian, consequently Gestaltist principles in their "hands-on" method. This topic will

to the phenomenological and pragmatist open-endedness of visual exploration, which may initially build on these fundamentals (especially for pedagogical purposes) but then swiftly go on to transcend any rule, principle or norm. Throughout this work, especially basic two-dimensional abstract shapes and two-dimensional abstract designs are used in order to exemplify and clarify the points made.

Today, we rely on a history of research that sought to investigate *creative design*, jointly *the teaching of design* as a function of *design theory*. Various intriguing precedents can be traced in theories of human creativity, its sources, and whether and how it can be accessed, developed and taught. Art and science have been joint enterprises since the Renaissance, with philosophy inquiring into their activities. But, methodical research into *creative design* as a field of study on its own began to take form in the last decades of the nineteenth century. At the highpoint of the Machine Age with the second Industrial Revolution in the early 1900s, creative design was increasingly discussed in terms of its structures, systems, methods and procedures. These frameworks were customarily identified with scientific thinking and scientific activity, but then began to frame design thinking and design activity as well.

My approach to creative design draws mainly from the shape grammar theory and is informed by the design theoretical and pedagogical inquiry developed throughout the late nineteenth and the twentieth century. I primarily focus on visual phenomena – visual shape, form and space, although shape grammars can be produced to capture different aspects or kinds of human experience, with, for example, labels, weights and so on. My approach also focuses on the idea that aesthetics, aesthetic experience and aesthetic understanding can be formalized, i.e., they rely on a fundamental formal structure that is built on fundamental abstract and geometric shapes and forms – points, lines, planes and solids, which can also be understood as a *visual language*. My definition of design, described as a creative and productive computational process, constitutes a big playground for practicing seeing (sensation), sensibility, discernment, judgment, and appreciation. In this computational design process, perpetual "embedding" through seeing shapes and applying rules and the algorithmic process of advancing designs constitute aesthetic experience.[25] In other words, aesthetic experience and aesthetic education are founded on the practice of continual embedding in the sensory-perceptual and action-based way.[26]

In order to elaborate on our understanding of human creativity in visual art and design, its relation to aesthetic experience and action, and our understanding of how it can be taught, in this chapter, I chronologically trace four definitions of design that inform our theories, teaching and research today: *1) visual design as aesthetics, 2) visual design as language, 3) visual design as science, 4) visual design as computation: design as a newly emerging – non-combinatorial and non-symbolic – theory of computation.*

Through these four definitions and thought structures, I briefly survey design theories and pedagogies that continue to inform our design studio conduct, method and curricula – our ways of teaching and learning. These four categories follow a chronological order, but also reflect the reverse-chronological route that I ended up pursuing in my discoveries of the connections as I deepened my

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be further explored in future research parallel to design education. Among many interesting resources: Stern, Catherine, Margaret Stern and Toni S. Gould. *Experimenting with Numbers.* Boston: Houghton Mifflin Co., 1950.

[25] The notion of embedding has been a core idea in shape grammars from the very beginning: Stiny, George. *Pictorial and Formal Aspects of Shape and Shape Grammars.* Basel, Switzerland: Birkhäuser Verlag, 1975. p. 131 – and onwards. Also see: Stiny, George. "What Designers Do that Computers Should." (pp. 17 – 30.) In McCullough, M., Mitchell, W.J. and Purcell, P. (Ed.s.) *The Electronic Design Studio.* Cambridge, MA: The MIT Press, 1990.

[26] Stiny, George. "Generating and Measuring Aesthetic Forms." In Carterette, E. C. and Friedman, M. P. (Ed.s.) *Handbook of Perception, Volume 10.* New York: Academic Press, 1978. pp. 133-152.

research inquiry. I begin by talking about *visual design as aesthetics*, elaborating on the classical theories of aesthetics up to the late nineteenth century experiential and pragmatist models described by John Dewey and William James. The shift from objects to experiences gave way to late nineteenth century modern design theories, especially those of the American modernists, who provided us with early models and formalisms in their descriptions of *visual design as language*. The view on visual design as language involved the construction of order and harmony by synthesizing abstract shapes, forms and compositions based on visual design principles. Advancing especially in the European and Russian modernism, the definition of *visual design as science* arose when theorists aspired to establish its objective, universal and normative foundations. In the second half of the century, early computational research looked at *visual design as computation*, bringing forward a prospective research area into human rationality, intellectuality and behavior.

Later computational theories like shape grammar theory revolutionized the notion of design as computation. This procedural, algorithmic and computational framework offered a generous but also rigorous formalism to seeing and generating new designs, capturing human "reasoning" in its various forms – capturing not only the rational aspects, which satisfy the cognitivist us, but also the phenomenological, sensory perceptual and corporeal characteristics of creative individuals. Shape grammars constantly remind us that cultivating the "sentient creator" is as important as learning to forbear the "cognitive miser".[27] In other words, visual design described as computation not only includes its other descriptions – design as science, design as language and the most elusive design as aesthetics – but also constantly reminds us of our sentient creativity.

In the classroom or the design studio today, we have developed certain ways of *talking* and *not talking* about creative design and its aesthetics. What we allow and include in our conversations of aesthetics and criticism, how we talk about aesthetics and conduct and respond to criticism point to critical issues of human creativity and imagination.[28] Surely, as in a Boolean operation or a Gestalt switch, what *is not* there proves as important as what *is*. What we avoid and exclude in the conversations, how we avert aesthetics-related topics and how we conduct and respond by sidestepping criticism tie into the critical issues that operate in design teaching, learning and pedagogy.[29]

In the directed design conversations and critiques of the studio, aesthetic issues are rarely addressed in an explicit manner. In the first-year of the design curriculum, students start with their

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[27] Ackermann, Edith. (2015) "Amusement, Delight and Whimsy: Humor Has Its Reasons that Reason Cannot Ignore." In Constructivist Foundations. Volume 10. Number 3. pp. 405 – 421. Stable URL: http://www.univie.ac.at/constructivism/journal/10/3/405.ackermann

[28] Smith, Ralph A. (Ed.) *Aesthetics and Problems of Education.* (Readings in the Philosophy of Education.) Urbana, Chicago, London: University of Illinois Press, 1971. Also see: Smith, Ralph A. *Aesthetics and Criticism in Art Education: Problems in Defining, Explaining and Evaluating Art.* Reston, Virginia: National Art Education Association, 2001.

[29] Here, the Burke Theorem seems to apply: "A way of seeing is also a way of not seeing – a focus upon object A involves a neglect of object B." Burke, Kenneth. *Permanence and Change: An Anatomy of Purpose.* Berkeley: University of California Press, 1984. [1935.] When we see a shape

we can see it as either two nested squares, or four adjacent triangles touching at the edges, or any other decomposition that we fancy. Once we apply a rule and do something to the shape, we temporarily focus on the "object A" and neglect the "object B", but we can always recognize it yet again with another rule if we are interested.

rigorous studio practice. *The Introduction to Design, The Foundations* or *Basic Design* (the Bauhaus *Vorkurs*) not only introduces students to the fundamental design skills, but also indoctrinates them on how to think about, receive and give criticism in the space of various studio interactions.[30] As pointed out in the Introduction, ideas regarding *function* and *structure* are often addressed head-on as they are easier and clearer to talk about. In contrast, points regarding *shape, form and aesthetic experience* are often handled in implicit, indirect and oblique ways. Often highly frustrated at first, students quickly learn that they are supposed to infer how their formal design can be improved by decoding the criticism they receive, often delivered in vague language that does not help them address the problem. Students also learn that some of this knowledge is tacit, that they need to engage in continual trial-and-error, and that they need to successfully navigate the mentor-apprentice relations.

In this dissertation, my position is to challenge these implicit and indirect ways of talking and doing by arguing that we actually have tools, in this case shape grammars, to address aesthetics heads-on, in an explicit manner. In the twenty-first century, we still practice in a studio tradition that was developed for another time and place, and one which unfortunately continues to obscure designerly contemplation of form, aesthetic experience and criticism.

Most accessible and familiar theories to beginners or students today, when we start talking about design and how it looks – its aesthetics – are the *classical* theories of beauty, truth and the representation. From a traditional viewpoint, beautiful artifacts are often understood "in the classical sense that they embody some kind of Golden Ratio in proportions, are composed of opulent materials, or sport eye-catching flourishes."[31] If we go a little deeper and unpack the topics of beauty, the explanations, experience and creation of it, we come to find theories at the junction of art and mathematics. The association of art and mathematics is usually made with regard to the Renaissance polymath, who cultivated mathematical genius along with scientific rigor, artistic talent and philosophical insight. This ideal is often represented in our minds by the precisely measured yet highly artistic *Vitruvian Man* of Leonardo da Vinci[32] or given an air of mysticism by the notion of a

[30] Lerner, Fern. "Foundations for Design Education: Continuing the Bauhaus Vorkurs Vision." *Studies in Art Education* 46.3 (Spring, 2005): 211 – 226.

[31] For a non-designer or beginner designer viewpoint, as discussed here, see: Budds, Diana. "The Real Story Behind Brutalism: Phaidon's new book *This Brutal World* is a photographic ode to one of the most polarizing modern architectural movements." *Fast Company, Co.Design.* Published on May 23, 2016. Online essay accessed at: http://www.fastcodesign.com/3059463/exposure/the-real-story-behind-brutalism

[32] It is fairly ironic that Leonardo da Vinci came to epitomize, to the artist and the layman, the merging between art and sciences through a predominantly visual (with an estimated 100.000 drawings and illustrations over his life time) but also strongly literary legacy. As Veltman (1986) spectacularly demonstrates, until their detailed treatment of the original materials, art historians had a very narrow and one-sided approach to da Vinci's work, which favored the literary over the visual, the artistic over the scientific. Research in the last decades of the twentieth century brought forth da Vinci's visuality – through paintings, sculptures, drawings, illustrations – in addition to the biased literary treatment that art historians was giving him, as well as showing the underlying consistent scientific nature of his work in addition to the artistic and aesthetic aspects. And also simply, Da Vinci's drawings and illustrations "speak" for themselves once in dialogue with the spectator. The literary bias continues to exist in our conversations on art and design, also in the design studio. See: Veltman, Kim H. (1986) *Linear Perspective and the Visual Dimensions of Science and Art (Studies on Leonardo da Vinci I).* In collaboration with Kenneth D. Keele. München: Deutscher Kunstverlag.

mathematical and aesthetic perfection that can guide design: the *golden ratio (golden proportion, golden mean)* and similar formulas of geometry in natural beauty or behind pictorial and spatial art.[33]

While these associations present an account of the Renaissance rigor, or the classical aesthetic movements that alluded to spirituality, they also offer a mystifying hence stifling view of the connection between artistic and mathematical endeavor. It is not an exaggeration to say that beyond most artistic and designerly "form" lurks always a mathematical structure; similarly, artistic and designerly creativity shares the same structures with mathematical, scientific and philosophical creativity.[34] If this is the case, then, how does one go about learning to be creative in art and design, understanding artistic and designerly form? How could mathematical insight about artistic and designerly form contribute to artistic form's value? And, conversely: how could artistic insight inform the ways we feel and think, the ways we sense, perceive and compute? Could mathematical thinking in the creation of form and composition guide our experience and creativity? Could our unique experiences and creative attitudes challenge and enrich the way we mathematically explain our works, our creative endeavors and our experiences?

The short answer to these questions is "yes, artistic and mathematical insight in art and design do inform each other"; my long answer would be this dissertation. For the answers to the questions of *how,* I focus on theories that have approached the problems of visual design to understand them formally, mathematically and computationally, but that remain within a strictly aesthetic and experiential framework. I ultimately lead up to the shape grammar theory and the invaluable worldview it offers to us to *see* and *be mindful of* the fleeting panoramas of the world, especially in the form of sensations and perceptions, and make use of these as we create aesthetic objects and experiences.

To reiterate, I treat ideas on aesthetic and experiential education as a function of the theorization and application of the *aesthetic* and *experience.* For this purpose, the following section focuses on the theories and descriptions of the aesthetic and experience. I trace the theories and descriptions that guide and model educational practices, and not particularly the teaching and training techniques in specific workshops, ateliers, schools or institutes. These particular educational practices can be traced in the resources detailed in the previous chapter. Here, instead, my aim is to get a deeper insight into the definition of aesthetic, experience and its relation to creative visual design – in other words, into that which we aim for when we are engaged in creative design practices, and the nature of our engagement.

2.1 Visual Design as Aesthetics

Since the ancient Greeks, the purpose of art has classically been described as creating "beautiful" and "harmonious" objects of art. Inquiries into the nature of beauty and harmony have been driving the theory and practice of art ever since. Over the centuries, other disciplines like philosophy and science also sought to develop unique insights into beauty and harmony as part of human experience and

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[33] Tatarkiewicz, Wladyslaw. *History of Aesthetics. (Volume I, II, III.)* Ed. J. Harrell. The Hague, Paris: Mouton.

[34] Lionel March, "Architecture and Mathematics Since 1960", pp. 7-33 in *Nexus IV: Architecture and Mathematics,* eds. Kim Williams and Jose Francisco Rodrigues, Fucecchio (Florence): Kim Williams Books, 2002. March clarifies, "Of course, every mathematical model abstracts from actuality and only deals with a limited number of factors and assumptions. In my view, such models are useful in questioning our prejudices and sharpening our understanding as long as the limitations are taken fully into account" (pp. 11 – 12.) On the other side, there is a dual nature to this enterprise: "Architecture [art, design], in its applications, demands the concretization of abstract mathematical statements" (p. 14).

creativity. In this context, it is useful to be aware that many of the philosophical and scientific ideas we refer to today entail modern thought structures. Aesthetics, for example, became an independent branch of philosophy at the end of the 1700s and expanded the definition of "aesthetic." Although our modern ideas in aesthetics feed significantly from the philosophical view of aesthetics, we still rely on a substantial tradition in artistic and aesthetic inquiry offered by the philosophy of art.

Ancient Greek thought devoted much effort to theorizing about beauty and harmony. In the classical theories, offered by Socrates, Plato and Aristotle, beauty was commonly regarded as a physical property intrinsic in objects (objective) and was not open to subjective evaluation. Plato (427 – 347 B.C.) subscribed to the notion of transcendental constants manifesting absolute beauty. When these constants were imprinted on physical objects, beauty became apparent through inherent order and proportion.[35] Aristotle (384 – 322 B.C.) furthered Plato's theory, but also focused on the "particular" properties of beauty that can guide us towards the "generals." Beauty, in Platonic and Aristotelian thought, also served as a model that could heighten human existence by constant aspiration to and imitation of it. One of Aristotle's biggest impacts came about when he advanced Plato's theory of imitation. He elaborated on education, of the moral sense, of character, and of spirit. Artistic engagement could be a vessel for purgation (catharsis) that could liberate and educate the human soul, an idea with which we are still very familiar today.[36]

In the collection of classical ideas, Platonic, Aristotelian, Pythagorean, Euclidean and Sophist philosophies are each interesting to consider in their own right, as well as the Greek traditions of artistic creation and skillful production.[37] Euclid and Pythagoras, however, deserve a special focus here because of their prominence as archetypal attempts that sought mathematical laws behind human experience, rationality and creativity. The target of their mathematical and scientific rigor was the unveiling of an inherent logic that encompassed all, from immediate human experience to a universal and cosmological order. This kind of explicit contemplation of physical and artistic form, form in immediate empirical experience and reasoning, and form in aesthetic experience and enjoyment, essentially relate to this dissertation.

When Pythagoras and Euclid, along with other ancient Greek thinkers, expanded the boundaries of mathematics and geometry into their abstract, clear and precise form, the ancient Greek tradition also revolutionized the world of thought and the practical fields that feed from intellectual progressions. They introduced superbly effective mathematical tools and scientific fundamentals, which still constitute today's disciplinary knowledge and are at the foundation of modern thought.[38] What

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[35] Plato. *Republic.* Translated with an introduction and notes by Robin Waterfield. Oxford; New York: Oxford University Press, 1998. Also see: Plato. *The Laws of Plato.* Translated with notes and an interpretive essay by Thomas L. Pangle. New York: Basic Books, 1980.

[36] Aristotle. *The Politics.* Edited by Stephen Everson. Cambridge [England]; New York: Cambridge University Press, 1988.

[37] The Greek notion of *techne* (technique) encompassed artistry and craftsmanship and played an important role in utilitarian aesthetics of *the good life.* As opposed to a disinterested and heavily contemplative understanding, *techne* implied knowledge of utility, application, principle and detail in the creative processes of crafting, making and doing.

[38] Foundationalist theories (foundationalism) philosophically assume that human inquiry and knowledge can be gradually and systematically built on particular foundations – fundamentals, beliefs, principles or axioms. On the other hand, non-foundationalist theories reject such foundations at the basis of human inquiry, knowledge or creativity.

rendered Pythagorean and Euclidean traditions so effective were their clear and intuitive explanations, formulas and rules in explaining various phenomena related to our "enlightened" – "first-hand" – human experience, which at first appeared chaotic but were gradually explained (rendered tangible and graspable) by their theories.[39]

The intellectual prowess in abstract mathematics and geometry not only manifested physically and sensorially in artworks, everyday artifacts, sculptures and architecture, but also radically affected the idea of *beauty*, which gradually solidified into a conception of *aesthetic beauty* that pertained particularly to visual and spatial arts. Hence, beauty became more intricately tied to visual and spatial sensory experience. With their rigor in the connection of art and mathematics (especially geometry), Greek thinkers advanced the core notions of *harmony*, *unity* and *order* in the theory of beauty. There was significant convergence of ideas about what beauty was, what it entailed and how it could be evaluated and measured: thinkers spoke about beauty as *charming* and that which gave *joy* to us mortals; that which pointed at the harmony, unity and order of the universe and the cosmos; that which had *symmetry* or *eurhythmy* (in oratory). The notion of symmetry was especially significant because it further defined *commensurateness*, *fittingness* and *appropriate measure* (or *appropriateness*) of form and design. Similarly, symmetry and eurhythmy established the notions of *proper rhythm* and *good proportion*.

Unity and harmony with the cosmos, as an expression of Divinity and with teleological influences, pervaded medieval thought throughout the Middle Ages.[40] The classical Greek notions, listed above, continued to assert their influence in medieval art and art treatises.[41] When the Renaissance polymaths brought the focus back to the human scale, they re-invented the connection between art and science. Da Vinci proposed that "the eye projects itself to the world" and anticipated modern approaches like phenomenology and embodiment. Filippo Brunelleschi (1377 - 1446) and Leon Battista Alberti (1404 – 1472) advanced "linear perspective" in order to capture the visual experience of the world on pictorial canvas.

While theorists were initially motivated to capture the first hand human gaze (subjectivity), novel techniques and technology soon contributed to the development of an objective and calculated understanding of the cosmos. As tools of *measuring* and *sensing* revealed more to artists and scientists, it gradually reinforced an objectivist, mechanical and deterministic worldview. The tools themselves, in a sense, became "disembodied" and "disinterested" observers of the truth in theorems and experiments; they became increasingly detached from embodied human spectatorship and observation, in the relationship of humans and the observed phenomena. This development in one way was coherent with the emergence of classicism in the Renaissance. Artists and theorists were increasingly interested in understanding the classical notions of beauty – such as symmetry, proportion, balance, regularity, restraint – and lay down governing "rules" that capture the relationships in the arrangement of elements in beautiful objects. The precursor ideas on arrangement, design and composition began to

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[39] Tatarkiewicz, Wladyslaw. *History of Aesthetics. (Volume I, II, III.)* Ed. J. Harrell. The Hague, Paris: Mouton.

[40] On Aquinas, see: Turner, Denys. *Thomas Aquinas: A Portrait.* New Haven: Yale University Press, 2013. On a comprehensive overview, see: Cahn, Steven M. and Aaron Meskin. (Ed.s.) *Aesthetics: A Comprehensive Anthology.* Malden, MA: Blackwell Pub., 2008.

[41] Particularly nineteenth century scholars led to the formation of a frequent misconception about the advancements attained in the Middle Ages. Often, a leap is thought to exist in the intellectual thought from the Greco-Roman philosophy to the Renaissance – or even to the establishment of the Cartesian philosophy. However, it is well-accepted today that medieval philosophers, especially as part of the Scholastic movement, had stellar contributions to various fundamental questions.

appear at this time, especially through Alberti.[42] It culminated in 1795, when the field of modern aesthetics became a philosophical discipline in its own right. German philosopher Alexander Gottlieb Baumgarten in particular named and introduced it as "the science of what is sensed and imagined" (Baumgarten, *Meditationes §CXVI*: 86-7).[43]

While the objectivist and scientific worldviews – along with the authority of *reason* – were championed in the early Enlightenment thought, theoretical strands arguing for subjectivity, phenomenology and embodiment (with a particular focus on sensations) were being developed throughout the seventeenth, eighteenth and nineteenth centuries in the development of modern philosophy of aesthetics. While introducing the mind-body conundrum, and everlastingly problematizing and severing the relationship of the mind and the body, Renee Descartes (1596 – 1650) introduced subjectivity to aesthetic understanding. With the shearing of "what is out there" (body) and "what is in there" (mind), even with the same inherent qualities of aesthetic objects, we could have varying and diverse aesthetic preferences.

John Locke (1632 – 1704) advanced the Cartesian view into his "primary qualities" and "secondary qualities." The inherent primary qualities of objects evoked subjective secondary qualities in observers, and the primary and secondary qualities were indeed nothing like each other. Secondary qualities were created by the sensation and perception of the observer – for instance colors, smells or tastes – by the capacities of sensing and interpreting the datum. Eventually, experience was in the aesthetic recipient's (observer's, experiencer's) mind rather than out there, which became an important lineage in aesthetic and empirical thought. The third Earl of Shaftesbury (Anthony Ashley Cooper, 1671 – 1713) also underlined the immediate of human sensation and perception – especially of beauty – but also theorized on the intellectual component of aesthetic experience. He maintained that after the aesthetic ideas (mind) were produced through a "disinterested aesthetic attitude," the association of these ideas intellectually contributed to the aesthetic experience of the object.

These centuries witnessed such an impressive rate of growth in discussions of art, design and aesthetics (for various reasons) that eventually the eighteenth century began to be referred to as the century of aesthetics with an abundant expansion of ideas beyond the classic notions. Frances Hutcheson (1694 – 1746) and Joseph Addison (1672 – 1719) progressed on Shaftesbury's ideas and furthered insight on the understanding of shape, form and "compound qualities" afforded by [aesthetic] objects. They also introduced new psychological notions (as discussed in the introduction of this chapter) as well as various new aesthetic notions, such as uniformity, variety, sublimity, novelty and

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[42] Alberti, Leon Battista. *On Painting.* Translated by Cecil Grayson; with an introduction and notes by Martin Kemp. London: Penguin Books, 1991. Alberti also defined ""Beauty: the adjustment of all parts proportionately so that one cannot add or subtract or change without impairing the harmony of the whole."

[43] Baumgarten, Alexander Gottlieb. *Meditationes philosophicae de nonnullis ad poema pertinentibus/Philosophische Betrachtungen über einige Bedingungen des Gedichtes.* Edited by Heinz Paetzold. Hamburg: Felix Meiner Verlag, 1983. English translation by Karl Aschenbrenner and William B. Holther. *Reflections on Poetry: Alexander Gottlieb Baumgarten's Meditationes philosophicae de nonnullis ad poema pertinentibus.* Berkeley and Los Angeles: University of California Press, 1954. Through its emancipation, the field of aesthetics started looking more deeply into the issues in art and aesthetics independent of other philosophical concerns, such as epistemological or ontological binds. To note, despite the objectivist attitude, the original Greek definitions – *aesthesis* standing for "sensing" and *aesthetiki* for "the discourse on the senses" -- still concerned themselves more with the perception and understanding of the objects. These definitions agreed to a more human-centered, embodied and active form of feeling, sensing and perceiving. Renaissance thought re-adjusted this focus and more severely detached the aesthetic object from the aesthetic recipient.

their compound rations. The scope of aesthetics from this point on was beyond mere beauty; Addison, for instance, defined aesthetic experience and aesthetic taste as a function of three features: sublimity, novelty and beauty. This did not stop William Hogarth (1697 – 1764), however, from still pursuing his rigorous search for the production of "linear beauty." He readdressed classical notions – fitness, variety, uniformity, simplicity, intricacy, quantity, size – and also introduced his serpentine-shaped "line of beauty" and "line of grace" as an objective basis for the creation of beautiful and graceful two-dimensional and three-dimensional lines.

David Hume (1711 – 1776) and Edmund Burke (1729 – 1797) were possibly the most influential British philosophers on aesthetic thought, with particularly strict subjective stances. Hume argued that beauty was purely in the mind and focused on the mind that contemplates and perceives it. More specifically, he investigated mental capacities and capabilities that introduce individuality in "the constitution of our nature, by custom, or by caprice." Similarly, Burke focused on the particular kinds of experiences evoked by beauty and their relation to properties like harmony, proportion or utility. In addition to the perception and judgment of beauty, Burke further elaborated on the notion of the sublime.

In addition to the strong British tradition in aesthetics, German tradition introduced key aestheticians, including Immanuel Kant (1724 – 1804), Friedrich Schiller (1759 – 1805) and Georg Friedrich Wilhelm Hegel (1770 – 1831). Out of these three, among others, I will focus on Kantian aesthetics, as it has offered us the first extensive descriptions of "aesthetic experience" as such. In a spectacularly colossal philosophical project, Kant aimed at understanding pure reason, practical reason and judgment or correspondingly knowledge, desire (interest) and feeling (sensing).[44] By so doing, he eventually resolved the rationalism-empiricism debate with his transcendental idealism and became the first philosopher to begin to successfully interlink mind and body. He presented a complex but fundamental theory for modern aesthetics: he found any endeavor futile in establishing rules or principles for beauty or the experience of beauty, subscribing to an entirely subjective interpretation.

In his aesthetics, Kant disassociated any practical interest or any cognitive concept from the judgment of beauty or delight. According to his theory, beauty did not require a cognitive concept and it relied on the reception and imaginative representation (noumenal world) produced from an entirely disinterested (non-purposive) experience of the phenomenal world. In his treatise on judgment, he further elaborated judgment as pure "taste" and not cognition, namely, as purely aesthetical or experiential and not logical or rational. With this separation, in fact, Kant liberated aesthetics from any conception or purposiveness. He purified aesthetics as only form and feeling. In aesthetic experience, we discerned (selected) parts in order to create our noumenal worlds from the whole phenomenal worlds. The process of discerning and judging corresponded to sensing and measuring. Furthermore, imagination was also responsible for processing the phenomenal world into the representational world. Therefore, once we sensed, judged and discerned, we then pursued to "count" and "compute" our

[44] Kant, Immanuel. *Critique of Pure Reason.* Translated, edited, and with an introduction by Marcus Weigelt; based on the translation by Max Müller. London; New York: Penguin, 2007. Also see: Kant, Immanuel. *Critique of Practical Reason.* Translated and edited by Mary Gregor; with an introduction by Andrews Reath. Cambridge, U.K.; New York : Cambridge University Press, 1997. See: Kant, Immanuel. *Critique of the Power of Judgment.* Edited by Paul Guyer; translated by Paul Guyer, Eric Matthews. Cambridge, U.K.; New York: Cambridge University Press, 2000.

sensations, judgments and discernments into imaginative entities to be experienced, pondered and understood.

Following the giant that was Kant was not easy. But, Romantics in the nineteenth century offered the way out by introducing "originality" as a virtue – and a virtue of aesthetics. If you are not in the habit of reading footnotes and skipped *Footnote 11*, Romantic philosopher Jean Jacques Rousseau (1712 – 1778) famously exclaimed "If I am not better than other men, at least I am different!" In the nineteenth century, philosophy's grip on aesthetics was loosened and poets, novelists and essayists took the flag to pursue aesthetics, like Rousseau and Johann Wolfgang von Goethe (1749 – 1832). Nineteenth century "Aestheticism" or the "Aesthetic Movement" also bloomed by arguing for "formalist (form-based) aesthetics" as a possible reaction to the sometimes socially and politically over-engaged Romantic aesthetics.[45]

In the pursuit of Romantic ideals, a highly interesting surge of educational ideas appeared in the eighteenth and nineteenth centuries that are worth detailing because they focused on the education of the senses and imagination. Starting from the education of children, educators began to propose lessons and classes that focused on progressive sensory-perceptual development and experiential skills. They sought more paced,[46] natural, organic and humanitarian ways for pupil's growth, with techniques that would liberate important virtues like imagination and creativity. Initial ideas proposed by Rousseau on sensory education were picked up and further advanced by other pedagogues, such as Johann Heinrich Pestalozzi (1746 – 1827), Friedrich Fröbel (1782 – 1852) and Maria Montessori (1870 – 1952), gradually solidifying into their unique techniques and methods.[47]

Rousseau criticized the formal education of the time, which over-emphasized intellectual development. He instead conceptualized students as "clean slates" and "innocent eyes" that needed to be educated through progressive sense-perception exercises. Similarly, despising "book-learning," Pestalozzi advanced his theory of sense-perception – abbreviated as the "ABCs of *Anschauung*" (ABCs of

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[45] Famous leading figures of the movement were Walter Pater (1839 – 1894), John Ruskin (1819 – 1900), Oscar Wilde (1854 – 1900) and Harold Bloom (1930 –). This movement also had a significant influence on drawing, painting and the decorative arts.

[46] In his teaching method, Pestalozzi proposed that subjects should be given to students in a gradual manner appropriate to their individual capabilities. He was keen on investigating the sequences of exercises that could be given to students, as well as the adjustability of the psychological gradient. Pestalozzi thus approached the cognitive theories of the Swiss developmental psychologist Jean Piaget (1896-1980) that were to appear much later. In his extensive research in child development and learning, Piaget showed that development occurs in stages and that knowledge builds; a child cannot grasp *concept c* without first understanding *concept a* and *concept b.* Pestalozzi urged educators to observe students closely and evaluate their capabilities in order to assign meaningful exercises for them at particular stages. Piaget, Jean. *The Language and Thought of the Child.* Translated by Marjorie Gabain; preface by E. Claparède. New York: World Publishing Co., 1967.

[47] Rousseau, Jean-Jacques. *Émile.* Translated by Barbara Foxley; introduction by André Boutet de Monvel. London : Dent ; New York ; Dutton, 1966. Also see: Rousseau, Jean-Jacques. *The Social Contract.* Translated by Maurice Cranston. New York: Penguin Books, 2006. [1762.] On Pestalozzi, see: Silber, Kate. *Pestalozzi: The Man and His Work.* London: Routledge and Kegan Paul, 1960. On Fröbel, see: Fröbel, Friedrich. *The Education of Man.* Translated from the German and Annotated by W. N. Hailmann. New York; London: D. Appleton&CO., 1887. Also see: Fröbel, Friedrich. *Friedrich Fröbel's Pedagogics of the Kindergarten: Or, His Ideas Concerning the Play and Playthings of the Child.* D. Appleton, 1899. On Montessori, see: Montessori, Maria. *The Montessori Method.* [Translated from the Italian by Anne E. George] Introduction by J. McV. Hunt. New York: Schocken Books, 1964.

sense-perception) – as the foundation of knowledge, and therefore of learning.[48] With this theory, he aimed to achieve sense-perceptual and experiential knowledge (open experience) before verbal and conceptual knowledge (that fixes the world). Fröbel developed his "kindergarten method" with the introduction of progressing kits and gifts, which was to be played and contemplated by pupils under the guidance of mentors. Montessori further developed tools for sensory education, introducing various sensory and psychological gradients in seeing, hearing, touching. The relative sensations generated by progressing bells and chimes, for instance, educated student's ear as well as the mathematical insight associated with that particular progression and "measure."

The empirical focus on aesthetics continued to grow with philosophical traditions like phenomenology and German idealism. However, the more radical shift came from American modernism with the introduction of pragmatist philosophy. John Dewey's emphasis on process and experience reintroduced art as a process – a process of experiencing and a process of creating.[49] Reminiscent of Romantic aesthetics, the lines between the creator, the artist, the spectator and the critic thus became significantly blurred. Parallel to Kant's notion of discernment, William James introduced the idea of *embedding* into our immediate experiences of the world and its phenomena. Embedding is humans *making sense* of the datum, *making truth* and *making meaning*; however, James was careful enough to distinguish *Anschauung* from his *Weltanschauung* (worldview). Our specific interests always create a filter on our sense-perception. We can only engage locally and individually with a global World. We can only progress step-by-step in the World, bit by bit, by making sense, making truth and making the world, into eventually making the stream of consciousness.

Following this theory, James successfully argued for philosophical plurality – rather than a dualism, nor even monism: there could be multiple truths when we observe the world, make discernments, sensorially embed, count our parts, reason and take action.[50] Hence, James introduced the possibility of *pragmatist aesthetics*, although his philosophical project did not explicitly include aesthetics. James's acquaintances at Harvard University, psychologist Hugo Münsterberg (1863 – 1916) and philosopher George Santayana (1863 – 1952), as well as design theorists at the School of Art, created a significant dialogue on form, design and aesthetics at the turn of a century. A true shift occurred with the understanding that pragmatic experience, reasoning, decision-making and action could guide pluralistic and idiosyncratic creative and productive processes – and possibly, above all, art and design.

In addition to the modern theories of Dewey, James and Santayana, those of Benedetto Croce (1866 – 1952), Ernst Cassirer (1874 – 1945) and Susanne Langer (1895 – 1985) introduced important ideas in aesthetics in the early twentieth century. Even more essentially at this period, mathematical

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[48] The original German words for Pestalozzi's fundamental principle are *Anschauung* or *Anschauungsunterricht*. *Anschauung* is usually translated as "sense-perception". It can also be translated as "sense-impression". As Kilpatrick notes, *Anschauung* can be noted as "object lessons" or "visual instruction"; however, this is a limited translation and an inadequate way of formulating the doctrine. In some dictionaries, *Anschauung* is defined as a direct and pure observation with as little rational insight as possible. Kilpatrick, William H. "Introduction". In *The Education of Man: Aphorisms*. By Heinrich Pestalozzi. Preface and Introduction by William H. Kilpatrick. New York: Philosophical Library, 1950. Also see: Pinloche, A. *Pestalozzi and the Foundation of the Modern Elementary School*. New York: Charles Scribner's Sons, 1901.

[49] Dewey, John. *Art as Experience*. New York: Capricorn Books, 1958. On educational extensions of the pragmatist philosophy, see: Dewey, John. *Experience and Education*. New York, NY: Kappa Delta Pi, 1938.

[50] For a discussion on the possibility of plural truths and logical statements, see: Shusterman, Richard. *Pragmatist Aesthetics: Living Beauty, Rethinking Art*. Lanham, Md. : Rowman & Littlefield, 2000.

contemplations on form and its aesthetics began to take shape in prominent works, such as mathematician George David Birkhoff's *Aesthetic Measure.*[51] A possible model for aesthetics, aesthetic experience, its measure and its calculation were introduced in this seminal work. Birkhoff did not propose an *absolute* measure in the classical sense, but proposed a pragmatic step-by-step examination and exploration of experience through particular formulae and procedures.

In recent years, we experience a resurgence of the corporeal and phenomenological attitude both in phenomenological aesthetics[52] and in issues of art and design.[53] Fortunately, this revival has come with significant focus on aesthetic experience, but yet again also with excessive reliance on philosophical, literary and verbal contemplation.[54] We also need the resurgence of sensory-perceptual, mathematical (formal) and procedural rigor in our aesthetic contemplations and treatment, which shape grammars can revive.

2.2 Visual Design as Language

Late nineteenth and early twentieth century theories typically defined the essential purpose and fundamental process of art and design as creating "beautiful compositions," through uniform, orderly and harmonious designs that conveyed artistic value.[55] An artistic composition was generated by effectively assembling – "composing, putting together" – "elements of art" based on "principles of art." Sounds, words, sentences and acoustic harmonies were organized to create compositions in music, poetry and literature. Similarly, spatial arts – painting, sculpture and architecture – used pictorial, visual, formal and spatial elements in order to create spatial compositions. In a way, the elements of art captured our *sensory engagement* and the principles of art captured our *judgment.*

When design was understood in this way – as the successful assemblage of *parts* and *wholes* with the aim of creating meaningful and communicable results, especially in the visual and pictorial domains – the conception emerged of *visual design* as *a visual language.* An analogy was established between natural languages and design languages. Creating visual designs and compositions was seen as conceivably equivalent to speaking or writing in various respects. In the process of creating pieces of writing, people usually used linguistic units, elements and forms, such as letters, words and sentences.

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[51] Birkhoff, George David. *Aesthetic Measure.* Cambridge, Mass.: Harvard University Press, 1933.

[52] The philosophical school of phenomenology, established by Edmund Husserl in mid-1800s (1859 – 1938), continued to grow throughout the nineteenth and twentieth centuries by significant proponents, such as Moritz Geiger (1880 – 1937), Roman Ingarden (1893 – 1970), Fritz Kaufmann (1891 – 1958), Jean-Paul Sartre (1905 – 1980), Maurice Merleau-Ponty (1908 – 1961), and Mikel Dufrenne (1910 – 1995). While all had important contributions to art and aesthetics, a number of significantly important contributions stand out: Geiger, Moritz. *The Significance of Art: A Phenomenological Approach to Aesthetics.* Center for Advanced Research in Phenomenology & University Press of America, 1986. Also see: Merleau-Ponty, Maurice. *The Primacy of Perception, and Other Essays on Phenomenological Psychology, the Philosophy of Art, History, and Politics.* Edited, with an introduction by James M. Edie. Evanston, [Ill.]: Northwestern University Press, 1964. On aesthetic experience, see: Dufrenne, Mikel. *The Phenomenology of Aesthetic Experience.* Translated by Edward S. Casey [and others.] Evanston [Ill.]: Northwestern University Press, 1973.

[53] Bhatt, Ritu. (Ed.) *Rethinking Aesthetics: The Role of Body in Design.* New York: Routledge, 2013.

[54] Sepp, Hans Rainer, and Lester Embree. (Ed.s.) *Handbook of Phenomenological Aesthetics.* Dordrecht; London: Springer, 2010.

[55] Dow, Arthur Wesley. *Composition: Line, Notan and Color.* Dover. Mineola, N.Y.: Dover, 2007 [1899]. Poore, Henry Rankin. *Pictorial Composition and the Critical Judgment of Pictures: A Handbook for Students and Lovers of Art.* New York, London: G. P. Putnam's Sons, 1903. Ross, Denman Waldo. *A Theory of Pure Design; Harmony, Balance, Rhythm; with Illustrations and Diagrams.* Boston: Houghton, Mifflin, 1907.

They *synthesized* these elements according to syntactic and grammatical rules. They conformed to or deviated from linguistic rules, explored a wide variety of linguistic devices, learned to interpret meaning, performed semantic analysis and manipulated sentences and paragraphs according to their liking. In a corresponding manner, when artists, designers and architects created visual designs and compositions, they used fundamental geometric shapes and forms, such as lines, planes and colors. They synthesized these elements based on syntactic and grammatical rules; they conformed to or deviated from visual-pictorial conventions, explored a wide variety of visual-graphical devices, learned to *read* pictures, performed semantic analysis and manipulated emerging visual forms and designs according to their liking.

The fundamental elements of visual design – basic abstract shapes and forms – have always been in the repertoire of artists, sculptors and architects. For the most part, they found their place in designs under the form of *the ornament*. The idea of visual design constructed by abstract shapes and forms became more familiar to designers after the Renaissance masters introduced pioneering theories and praxis in drafting, drawing and picture making. As referred to in the previous section, Alberti and Da Vinci, for instance, developed theories of perception – primarily seeing – based on underlying geometrical and mathematical laws. This particular Renaissance attitude distanced craft from art but married scientific and artistic theories underlying visual perception and creativity.[56]

The formulation of a design theory – consequently, design instruction – founded on abstract elements and logics of visual perception took place centuries later with the early American modernism. By this time, rapid industrialization had resulted in a continuous pressing need for educating workforce who was proficient in basics of art, drawing and industrial design. After almost two centuries of pedagogical research and theorizing on teaching in these areas for the industry, design was approached yet again from a rigorous formal and academic standpoint. Modernism in the United States, thriving at the end of the nineteenth century especially in the East Coast, introduced key figures in the new art and design theory as well as its fundamental key works.

The first book on *Composition* in visual design appeared in 1899, authored by the artist and design theorist Arthur Wesley Dow (1857 – 1922), adorned with the full title *Composition: A Series of Exercises in Art Structure for the Use of Students and Teachers*. Following shortly after, Denman Waldo Ross (1853 – 1935) published his *A Theory of Pure Design*, as well as Henry Rankin Poore (1859 – 1940) with his *Pictorial Composition and the Critical Judgment of Pictures*.

Along with others, Dow and Ross presented a modern notion of the creative artistic activity founded solidly on *composition* and *design*, which diverged from classical academic models.[57] In pictorial and spatial arts, classically, the role of composition and structure in the creation of the art object and establishing its aesthetics was not explicitly acknowledged. These modern theories recognized and

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[56] Alberti, Leon Battista. *On Painting*. Translated by Cecil Grayson; with an introduction and notes by Martin Kemp. London: Penguin Books, 1991. In design research today, Terry Knight has been exploring computational approaches to craft and making.

[57] In addition to being a leading figure in the American design theory, Dow was a highly influential educator and a productive creative artist, having taught at several major institutes as well as in his studio in Boston. He reached not only many students but also teachers, educators and theorists; at the Pratt Institute (1896 – 1904), at the New York Art Students League (1897 – 1903), at the Ipswich Summer School of Art in Ipswich, Massachusetts, which he founded and directed (1900 – 1907), and at Columbia University Teacher's College as the Director and Professor of Fine Arts (1904 – 1922).

formulated composition and structure as fundamental aspects of visual art and design. Different terms were already in periodical use in an interchangeable manner with the term *composition*, such as *design*, *form*, *visual ordering*, or *formal structure*, to point at the underlying visual diagram and purely formal structure of designs.[58]

Modern design theories instituted thus a "structural" (also referred to as analytical or synthetic) way of looking at the elements and principles of art. Pictorial elements in composition were the structural elements – such as lines, forms, or colors – as opposed to figurative or representational elements that might be depicted in the painting – such as figures, objects, or landscapes. These elements were visually ordered based on principles that determine the overall structural character of the artwork. Basically this underlying structure – which was formerly formulated as a hidden or secret geometry – now became visible, sensible, understandable – therefore, teachable.[59] The secret geometry was not so secret after all; geometry was "speaking" to us.[60]

In creating design and composition, basic elements (abstract shapes and forms) could be assembled (composed) according to certain principles that guided their ordering. Dow, for instance, defined three rudimentary structural elements – line, "notan" (black-white balance) and color – and a list of compositional principles that could be used to create harmony: opposition, transition, subordination, repetition, symmetry. Ross similarly identified the elements – position, line, outline, tone, and sequence – and a tripartite principle set that applies to the elements – harmony, balance, and rhythm – with a general composition rule to always seek higher Order leading to the Beautiful.[61] In the creation of *the Dow method*, Dow acknowledged art historian Ernest F. Fenollosa, whom he credited for initially emphasizing the *synthetic principles* in art that was inspired by musical composition.[62]

By focusing on structure and design, American design theorists also subscribed to the formalist aesthetics of the nineteenth century. The European formalists had begun to advance the notion that

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[58] Dow uses the term composition to formulate his theory, but occasionally touches upon the idea of design. See: Dow, Arthur Wesley. *Composition: Line, Notan and Color.* Dover. Mineola, N.Y.: Dover, 2007 [1899]. Ross successfully develops his entire theory in the modern notion of design. See: Ross, Denman Waldo. *A Theory of Pure Design; Harmony, Balance, Rhythm; with Illustrations and Diagrams.* Boston: Houghton, Mifflin, 1907.

[59] Bouleau, Charles. *The Painter's Secret Geometry: A Study of Composition in Art.* With a Preface by Jacques Villon; Translated by Jonathan Griffin. Allegro Editions, 1963.

[60] March, Lionel and Philip Steadman. *The Geometry of Environment: An Introduction to Spatial Organization in Design.* Cambridge, Mass. : M.I.T. Press, 1974. [1971.] Also see: Pedoe, Dan. *Geometry and the Visual Arts.* New York: Dover Publications, Inc., 1976.

[61] Resources on the arts of *drawing* and *painting* elaborate on similar sets of basic elements and basic principles in the form of design fundamentals (or design basics). They place additional focus on aspects like representation and meaning, but less on the role of composition and design in the generation of structure. For instance, art educator Orsini (1982) identifies three pairs of elements in drawing – mass and volume, line and contour, texture and tone – while touching upon the idea of compositional devices such as spacing and interval but with lesser focus on how the principles can be progressively applied to achieve good compositions. See: Orsini, Nicholas. *The Language of Drawing: Learning the Basic Elements.* Garden City, N.Y. : Doubleday, 1982. Although Orsini provides interesting progressive exercises in drawing, he does not extensively go into the details of compositional principles as a generative force behind drawings. Dow recalls the separation of the "representative (imitative)" and "decorative" schools in art and criticizes the "academic" tradition in art education for placing too much emphasis on the representation of reality, instead cultivating delight in composition. In drawing and painting, especially in the pedagogical sense, this emphasis still seems to prevail.

[62] Another influential Boston figure was Albert H. Munsell, who contributed to significant changes on drawing in public schools.

artistic engagement with the aesthetic objects can happen solely in a formal (form-based) manner. Formal engagement, in this sense, connoted direct perceptual engagement with the aesthetic object as the perceptual content – or the corporeal "form" – detached from its ancillary content, such as its meaning, representation, artist, period, respective movement, or social, political, and historical implications. The fundamental assumption was that the meaning and significance of the design object laid within the object itself. The abstract visual language of visual art and design – based on shapes and its structure – complimented formalist aesthetics and aspirations.

With the undertakings of European and Russian schools, visual design as language and its formalisms began to gradually lose their pluralistic-pragmatic roots and began gradually to obtain an institutionalized foundational-positivist stance. Although teachers maintained a plurality of theories and approaches in the avant-garde design schools *Bauhaus* and *VKhUTEMAS*, over time, the basic abstract elements and the visual design languages were taken as the fundamental vocabulary of our visual world. With the scientific principles borrowed from Gestalt psychology and the philosophical framework from logical positivism, the particular visual language began to claim objectivity and universality, approaching a scientific language of vision. The formulation of visual design as a visual language exposed it to formalisms that were *combinatorial* nature, as well as its scientification into objectivist theories. Despite having a sensory foundation, the logical framework imposed by linguistic formalisms paved the way for the re-invention of a science of visual design, or design as a visual science.

2.3 Visual Design as Science

The turn of the twentieth century and the first decades witnessed an ever-increasing denotation to creative practices and their sciences. This denotation motivated inquiries into understanding the relationship between design and science: was a *design science* or a *science of design* possible? Two specific periods of modern design history, in the 1920s and 1960s, are marked by a growing push towards the "scientification" of design.[63] Starting in the early decades of the twentieth century, better designed, more efficient and more optimized products were sought after. These products better suited the needs and ideals of a modern society that strove to adopt rational ways of organization. In the 1960s, the same qualities were demanded – this time not only of design products but also of "scientized" design processes.

The scientific approach to design and corresponding design pedagogy firstly culminated at the renowned design school the *Bauhaus*. *Staatliches Bauhaus* in Weimar was established in 1919 under the direction of Walter Gropius. Despite the politically and economically tumultuous conditions existing after WWI, the school developed strong modernist ideals and ambitions, some of which would later come to be regarded as hard-headed or naïve. It established its widely influential curriculum, the major influence of which has been the introduction of the *Basic Course* that was envisioned as the prerequisite general foundation to specialized studies. In the renowned diagram of the curriculum, the content of the Basic Course was shortly defined as "elementary study of form and study of materials in the basic workshop."

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[63] Cross, Nigel. "From a Design Science to a Design Discipline: Understanding Designerly Ways of Knowing and Thinking." pp. 41 – 54. In Michel, Ralf, ed. *Design Research Now.* Basel, Switzerland; Boston: Birkhäuser, 2007. On design methods, also see: Cross, Nigel and Robin Roy. *Design Methods Manual.* Prepared for the course team by Nigel Cross and Robin Roy. Milton Keynes: The Open University Press, 1975.

As various scholars have pointed out, the Bauhaus was not a uniform and rigid institution but rather "a changing and often divisive coalition of students, faculty and administrators."[64] The school exhibited constant dynamism especially with the flux of influential educators, introducing different ideas, exercises and practices. Remarkably, what was mostly shared and promoted was the belief in a universal visual language – a grammar – that was built on elementary shapes, colors, and their associations. This grammar was summarized by Wassily Kandinsky's formula "the dynamic yellow triangle, the static red square and the serene blue circle," which served as the ABCs of the Bauhaus visual grammar, recalling Rousseau's innocent eye and the Pestalozzian *ABCs of Anschauung*. The formula appeared repeatedly in Bauhaus educators' works and their student assignments.[65]

The abstract visual shapes and the visual language were initiated as predominantly pedagogical tools. Paul Klee's *Pedagogical Sketchbook* introduced a dynamic progression from points to lines to planes in the process of learning the visual languages.[66] Wassily Kandinsky's *Point and Line to Plane* studied the processes of form explorations in his *nonobjective* art.[67] In *Language of Vision*, György Kepes studied the liberation of plastic elements, which ultimately redefined our understanding of art and design.[68] Josef Albers taught and published extensively, emphasizing above all the subjectivity and plurality of sensation and perception for *opening the eyes* in his design teaching.[69] Johannes Itten laid down a basic course curriculum for education in design and form.[70] Books that center on the study and teaching of design from basic elements, to design principles, to geometry and structure, to visual organization and finally to form, design and composition continued to appear throughout the twentieth century, and continue to do so today.[71]

Although many of these independent design theorists maintained their own theoretical stances, the abstract visual shapes and forms could not escape the fate of becoming building blocks of a universal

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[64] Lupton, Ellen and J. Abbott Miller. (Ed.s.) *The ABCs of [triangle square circle]: the Bauhaus and Design Theory*. New York: the Cooper Union for the Advancement of Science and Art, 1993. p. 2.

[65] The yellow triangle, red square and blue circle appeared over and over again in Bauhaus educators' work and their assignments to students.

[66] Klee, Paul. *Pedagogical Sketchbook*. Introduction and translation by Sibyl Moholy-Nagy. New York: F.A. Praeger, 1953.Also see: Klee, Paul. *The Thinking Eye*. Edited by Jürg Spiller. London, Lund Humphries; New York, G. Wittenborn, 1969. [1961.]

[67] Kandinsky, Wassily. *Kandinsky, Complete Writings on Art*. Edited by Kenneth C. Lindsay and Peter Vergo. Boston: G.K. Hall, 1982. Also see: Poling, Clark V. *Kandinsky's Teaching at the Bauhaus: Color theory and Analytical Drawing*. New York: Rizzoli, 1986.

[68] Kepes, György. *Language of Vision*. Introductory essays by S. Giedion and S. I. Hayakawa. Chicago: P. Theobald, 1944.

[69] Albers, Josef. *Homage to the Square*. New York: Sidney Janis Gallery, 1964. Also see: Albers, Josef. *Interaction of Color*. New Haven [Conn.] : Yale University Press, in association with The Josef and Anni Albers Foundation, 2009. For opening the eyes, see: Horowitz, Frederick A. *Josef Albers: To Open Eyes; the Bauhaus, Black Mountain College, and Yale*. Frederick A. Horowitz and Brenda Danilowitz. London: Phaidon, 2009.

[70] Itten, Johannes. *Design and Form: The Basic Course at the Bauhaus and Later*. New York, Cincinnati, Toronto: Van Nostrand Reinhold Company, 1975.

[71] Graves, Maitland. *The Art of Color and Design*. New York, Toronto, London: McGraw-Hill Book Company, 1951. On principles, see: Collingwood, R. G. *The Principles of Art*. New York: Galaxy Books, Oxford University Press, 1958. On design elements, see: Anderson, Donald M. *Elements of Design*. New York: Holt, Reinhart, Winston, 1961. On the specific principle of Notan, see: Bothwell, Dorr and Marlys Mayfield. *Notan: The Dark-Light Principle of Design*. New York: Dover Publications, Inc., 1968. On visual form, see: De Sausmarez, Maurice. *Basic Design: The Dynamics of Visual Form*. New York: Reinhold, 1969. On becoming visually literate, see: Dondis, Donis A. *A Primer for Visual Literacy*. Cambridge, MA: The MIT Press, 1973.

language of vision. Fixed with universal meaning, shapes began to lose their open-endedness and purely sensorial nature and became signs. The Bauhaus faculty's close dialogues with the pioneers of the newly emerging Gestalt psychology were exciting; indeed, they opened up new conversations on the psychology of sensing, cultivating subjectivity, ambiguity and *insight.* However, partially biased with the Universalist aspirations, the laws and principles borrowed from Gestalt psychology fell into the danger of becoming prescriptive rules and rubrics at the school. The concurrent dialogues of the Bauhaus faculty and students with the philosophers of the Vienna Circle encouraged the logical positivist opinions.

Explicit enthusiasms and incentives towards the scientification of art and design as such became an integral part of the twentieth century modern movement. *De Stijl* artist Theo van Doesburg epitomized novel desires towards establishing a rigorous objective foundation for design and methodizing its advancement. In their manifesto, signed by van Doesburg, van Eesteren and Rietveld, *De Stijl* artists called for a collective effort to lay down the definition of human creativity, founded on scientifically and objectively established laws:

> Until now the domain of human creation and its constructive laws have never been examined scientifically. It is impossible to regard these laws as imaginary. They exist. One can only define them by collective work and by experience .... Our epoch is hostile to every subjective speculation in art, science, technique, etc. The new spirit, which already governs almost all modern life, is opposed to animal spontaneity, to nature's domination, to artistic flummery and cookery. In order to construct a new object we need a method, that is to say, an objective system.[72]

Similar sentiments were echoed by the modernist architect Le Corbusier with his description of the house as a "machine for living."[73] He envisioned a "modern architectural science" that defined creativity as a mechanical and rational problem-solving activity. He formulated the house as consisting of "a regular sequence of definite functions;" these functions were then trafficked into a precise, economical and rapid system. The majority of the Modern Movement thinkers held a keen aspiration, as observed in the exclamatory remarks of *De Stijl's* and Le Corbusier's manifestos, to cut away the "old" values of human endeavor and to found it on the "new" ones. The new values of human creativity and human consciousness were designated as objectivity, universalism, certainty, rationality and calculative determinacy.[74] These values were commonly understood as being "scientific" and were to replace the erstwhile values of creativity and consciousness. Subjectivity, individualism, uncertainty, irrationality, naturalism-organicism, spontaneity and speculative exploration became undesirable.

Inquiries into the relationship of science and design were alive throughout the 1930s to 1960s in numerous disciplines. After the prominent epoch at the Bauhaus, the architect Walter Gropius kept the question alive, *"Is there a science of design?"* as recorded in his exemplary writings and lectures in his tenure 1937 – 1952 as chairman of the Department of Architecture at the Harvard University. Other

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[72] Van Doesburg, Theo, Cornelis van Eesteren and Gerrit Thomas Rietveld. *Towards a Collective Construction (Vers une construction collective: manifeste V du Groupe De Stijl.).* Paris: *De Stijl, VI,* 1923. p. 89.
[73] Le Corbusier (pseud.). *Towards a New Architecture.* Translated from the French by Frederick Etchells. London, Architectural Press, 1946.
[74] Van Doesburg, Theo van et al. *Manifest of De Stijl I.* 1918. The manifesto was generated with the collaborative work of numerous important artists, poets and architects, such as Theo van Doesburg, Robert van T. Hoff, Vilmos Huszar, Antony Kok, Piet Mondrian, George Vantongerloo and Jan Wils.

faculty, retired from the Bauhaus, went on to further advance their own design theories into influential paradigms. They did not necessarily aspire for a scientific bearing, but always stayed relevant to the psychology of perception and design.

In the 1960s, theories toward the scientification of design fully rematerialized through the movement that came to be known as the "design methods movement."[75] A London "Conference on Design Methods" was organized by the leading figures Jones and Thornley and held in 1962. It has been heralded as the key moment in the history of *design research*, which established design methodology, science and research as new fields of inquiry.[76] The conference showcased rigorous proposals that took design on scientific, explicit and formalized grounds. Theories were often complemented by rigorous applications, including the employment or development of new scientific and computational tools.

By this decade, a new excitement had taken shape about design as a potential force in addressing world problems. Computational theory and research, which initially emerged from military applications, were seen in a new light as tools to comprehend and solve complex human issues. In the context of the 1960s social turmoil and campus movements, design and technology presented alternatives to politics or economics in effectively dealing with, for instance, industrial or environmental topics. Radical technologist Buckminster Fuller echoed this excitement and saluted a complete "design science revolution" that rested on science, technology and rationalism.[77] Herbert Simon recast the essence of this new paradigm (as distinct from "the natural sciences) in his book *The Sciences of the Artificial* that studied person-made artifacts and systems.[78] Equally important, Simon issued a request for the adoption of the new design paradigm in education under a new definition, which he meticulously fleshed out. He detailed an encompassing design subject for the curriculum, applicable to all professional disciplines. For this purpose, dropping the vocationalism, professional schools could "reassume their professional responsibilities just to the degree that they discover and teach a science of design, a body of intellectually tough, analytic, partly formalizable, partly empirical, teachable doctrine about the design process."

2.4 Visual Design as Computation

As discussed in the previous section, learning and teaching how to make art and how to design often start with learning the *visual languages* and familiarizing oneself with the fundamentals of pictorial, visual and spatial worlds. In visual communication, information is organized and conveyed primarily through visual shapes, forms, colors and textures; unlike in natural language, where narratives are

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[75] Upitis, Alise. "Nature Normative: The Design Methods Movement, 1944-1967." Doctoral dissertation. Department of Architecture. Massachusetts Institute of Technology, Cambridge, MA, 2008. URI: http://hdl.handle.net/1721.1/45943

[76] Jones, Christopher J. and D. G. Thornley. (Ed.s.) Conference on Systematic and Intuitive Methods in Engineering, Industrial Design, Architecture and Communications (1962.) *Conference on Design Methods; papers.* Edited by J. Christopher Jones and D. G. Thornley. Oxford, New York: Pergamon Press, 1963. Also see: Jones, J. Christopher. *Design Methods.* John Chris Jones; with prefaces by C. Thomas Mitchell and Timothy Emlyn Jones, and with additional texts. New York: John Wiley & Sons, 1992.

[77] Fuller, R. Buckminster. *The Design Science of R. Buckminster Fuller.* A traveling exhibit organized by the Museum of Science and Industry in Chicago and made possible by a grant from the National Endowment for the Arts. Chicago: Museum of Science and Industry, 1973.

[78] Simon, Herbert. *Sciences of the Artificial.* Cambridge, MA: The MIT Press, 1996. [3rd Edition, 1969.]

formed by weaving letters, words and sentences together. Visual and spatial compositions are at once "read" and created based on the reader's – or designer's – interpretation (projections, embedding) and moves (decisions about design rules, principles and semantics.)

Whether artists and designers are conscious of it or not, they all "speak" in visual languages; and what's more, their manners of speech are more akin to Austin's "speech-acts" (performative in nature) than to Saussure's de-contextualized re-descriptions (disengaged verbal accounts).[79] In their creative activities, they also dwell in the realms of seemingly "chaotic" but simultaneously "systematic" modes of inquiry that embody sensation, perception and reasoning.

Mathematical and scientific theories of design have indeed described the artist or designer's mode of inquiry as an intelligent form-giving human activity, entailing various events and episodes, which can be *formalized.*[80] *Formal systems* or *formalisms* seek to explain such processes based on the idea that behind apparently messy meanderings of insight-producing moves, by designers or artists, there have to be some underlying laws and regularities that can be formulated and captured by a formal system, and which the human mind is capable of comprehending.

We are quite familiar with formal systems. The sciences, mathematics and law are all formal systems that we are part of; spoken and written language can be understood in formalisms like Chomsky's generative grammars. There can be multiple formalization of the same material world; i.e. in physics, Newton's classical mechanics explain motions of physical objects in the universe through force; another formalization, Einstein's general relativity, does the same by modeling space-time. On the other hand, mathematics is a formal language that is independent of its object of study. It can describe, articulate and formalize any material system without ontological significance.

Elaborating on the material and formal systems in our visual world and our interaction (or "coupling"[81]) with it, design researchers and theorists seek to understand, describe and formalize creative art and design processes. After the early accounts of visual design as a language, as discussed in the previous section, art and design were taken as open-ended but structured enterprises since the early decades of the twentieth century. Modernist avant-gardisms, art movements like cubism and abstract expressionism, and constructivism collectively contributed to the re-description of creative art and design as continual and extendable processes.[82] Creative processes were no longer taken as exhaustible and finite, as ends in themselves, and as terminal once a "perfected" and "complete" outcome is reached.[83]

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[79] Ackermann, Edith. (2015) "Amusement, Delight and Whimsy: Humor Has Its Reasons that Reason Cannot Ignore." In Constructivist Foundations. Volume 10. Number 3. pp. 405 – 421. Also available at: http://www.univie.ac.at/constructivism/journal/10/3/405.ackermann

[80] Smithers, Tim and Wade Troxell. "Design is Intelligent Behavior, but What's the Formalism?" Artificial Intelligence for Engineering, Design, Analysis and Manufacturing, Volume 4, Issue 02, May 1990. pp. 89 – 98. doi: 10.1017/S0890060400002286.

[81] Noë, Alva. *Action in Perception.* Cambridge, Mass. : MIT Press, 2004.

[82] Martin, Leslie, Ben Nicholson, and Naum Gabo. (Ed.s.) *Circle: International Survey of Constructive Art.* New York: Praeger Publishers, 1971 [1937].

[83] A classical understanding of composition is evident in Alberti; he asserts "beauty: the adjustment of all parts proportionately so that one cannot add or subtract or change without impairing the harmony of the whole."

As Russian avant-garde artists tried to demonstrate – like Karl Ioganson, for instance – there was a revolutionary shift *from composition to construction*.[84]

The early decades of the twentieth century also witnessed significant revolutions in psychology, physiology, theories and application in computing, artificial intelligence and technology.[85] All these advancements came to bear fundamental shifts in our understanding of the body, the mind, their potential analogues, their interactions with the environment, the particular mechanisms of these interactions, and especially creative and productive reasonings as functions of these interactivities. At the same time, mathematical, logical and formal theories of computation began to produce successful theories and formalisms studying various material systems.

Beginning with the early formal theories of computation of Alan Turing (1912 – 1954), Kurt Gödel (1906 – 1978) and Alonzo Church (1903 – 1995), novel computational production systems and formalisms were advanced by theorists throughout the decades that followed. Among others stood production systems (canonical systems) developed by Emil Post, generative grammars proposed by Noam Chomsky, pattern grammars (pattern-shape recognition) advanced by King-Sun Fu and shape grammars created by George Stiny and Jim Gips.[86]

Shape grammar theory, formulated by George Stiny and James Gips in the 1970s, proposed the notion of *visual design as a creative (productive) computational activity*. In other words, it formalized visual and pictorial aspects of creative design. Shape grammar theory offers a systematization that allows designers not only to formalize but to phenomenologically handle visual form and composition.[87] Shape, in the shape grammar theory, is defined as a finite arrangement of elements – i.e., points, lines, planes or solids. In art and design, shapes are brought together in specific spatial relationships in order to create designs. The dictionary of spatial elements and the system of rules generate formal compositions.

According to shape grammar theory, shapes are the elementary constituents and materials of visual language. Fundamental shapes are the fundamental geometric entities: points, lines, planes and solids. With various operations performed on the fundamental primitives, complex shapes and forms can be obtained. In the creation of artworks or designs, designers play with and experiment with visual material. Design processes carry on as designers continually stumble upon new discoveries, work with emerging shapes, and assign new meanings to them.

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[84] Gough, Maria. "In the Laboratory of Constructivism: Karl Ioganson's Cold Structures." *October* 84 (1998): 91-117. Stable URL: http://www.jstor.org/stable/779210

[85] Design had been the subject of scientific formal study as an intelligent human activity since the pioneers in artificial intelligence (AI) John McCarthy, Alan Newell, Herbert Simon and Marvin Minsky developed an interest in it as "the sciences of the artificial", which modeled the material. "The sciences of the artificial", a phrase coined by Simon and adorns his famous book as the title, studied complex natural phenomena and their models, as well as design as a complex productive process. Simon, Herbert. *Sciences of the Artificial.* Cambridge: The MIT Press, 1996 (1969).

[86] For a more detailed survey of theories of computation, see: Knight, Terry. "Slow Computing: Teaching Generative Design with Shape Grammars." In *Computational Design Methods and Technologies: Applications in CAD, CAM, and CAE Education.* Ed. Ning Gu and Xiangyu Wang. Hershey, PA: IGI Global, 2012. pp. 34 – 55.

[87] Stiny, George. *Pictorial and Formal Aspects of Shape and Shape Grammars.* Basel, Switzerland: Birkhäuser Verlag, 1975. Also PhD dissertation, System Science Department, University of California, Los Angeles. Gips, Jim. *Shape Grammars and Their Uses: Artificial Perception, Shape Generation and Computer Aesthetics.* Basel, Switzerland: Birkhäuser Verlag. Also PhD dissertation, Computer Science Department, Stanford University, Stanford, California.

Taking "seeing" as the basis, shape grammar theory proposes the use of shape grammars for both the analysis of existing designs and the generation of new ones. Contrary to commonly employed computational approaches in design, used in CAD and other generative systems in drafting and modeling software, shape grammars deal with design in a non-symbolic manner. Because of their "analog" nature, shape grammars enhance creativity in the design studio, allowing for a continuous and open design process through "shape embedding" and perceived "shape identities" that permit multiple design interpretations to emerge and transform as one goes on.[88] Capitalizing on these ideas, shape grammars introduced the notion of "algorithmic aesthetics:" computationally and scientifically rigorous, but also sensory-perceptually, phenomenologically and pragmatically open *computational aesthetics*.[89]

The first shape grammar classes were taught by Stiny at UCLA in the 1980s. The pedagogy of shape grammars and teaching design with shape grammar methodology was initially theoretically discussed by George Stiny in his *Kindergarten Grammars*.[90] Relating the pedagogy of Fröbel's kindergarten *to the studio method*, Stiny offered a constructive approach to the design studio through student's formal (aesthetic), sensory-perceptual and computational engagement, with the help of a mentor or instructor. In other words, sensory and aesthetic education, earlier discussed by various aestheticians and pedagogues, could be rigorously and computationally studied with the formalism of shape grammars. His theory continues to reveal and inform pedagogical opportunities today, in the teaching of form, design and composition.

Building on shape grammar theory, Ulrich Flemming developed pedagogical models, advanced curricula and implemented computer applications at the Carnegie Mellon University (CMU).[91] Terry Knight contributed significantly to the integration and development of shape grammars in design education through her early classes at the University of California, Los Angeles (UCLA), her classes at MIT, and her novel theories and methods in the field.[92] With the goal of "original design," Knight proposed a variety of pedagogical practices, ranging from creating original designs, authoring grammars, transforming grammars, to analyzing existing art and architecture.

Due to the growing number of students and academics involved in shape grammar theory, research and applications, shape grammars today have expanded around the world. Shape grammar teaching methods have been developed and implemented at numerous institutes.[93] For example, Mine

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[88] Stiny, George. *Pictorial and Formal Aspects of Shape and Shape Grammars.* Basel, Switzerland: Birkhäuser Verlag, 1975. Stiny, George. *Shape: Talking about Seeing and Doing.* Cambridge, Mass.: The MIT Press, 2006.
[89] Stiny, George, and James Gips. *Algorithmic Aesthetics: Computer Models for Criticism and Design in the Arts.* Berkeley, Los Angeles, London: University of California Press, 1978.
[90] Stiny, George. "Kindergarten Grammars: Designing with Froebel's Building Gifts." *Environment and Planning B* 7 (1980): 409–462.
[91] Flemming, Ulrich. "Syntactic Structures in Architecture." (pp. 31 – 47.) In McCullough, M., Mitchell, W.J. and Purcell, P. (Ed.s.) *The Electronic Design Studio.* Cambridge, MA: The MIT Press, 1990.
[92] Knight, Terry. "Designing with Grammars." *CAAD Futures Digital Proceedings.* 1991. pp. 33 – 48. On education and practice, see: Knight, Terry. "Shape Grammars in Education and Practice: History and Prospects." September 14, 2000. Stable URL: http://www.mit.edu/~tknight/IJDC/ Also see: Knight, Terry. "Applications in Architectural Design, And Education and Practice." Report for the NSF/MIT Workshop on Shape Computation. Department of Architecture, School of Architecture and Planning, Massachusetts Institute of Technology, Cambridge, MA. April, 1999. Also see: Knight, Terry W. *Transformations in Design: A Formal Approach to Stylistic Change and Innovation in the Visual Arts.* Cambridge; New York: Cambridge University Press, 1994.
[93] Celani, Gabriela. "An Educational Experiment with Shape Grammars and Computer Applications." *International Journal of Design Computing* 3 (2002). On another teaching method initiated by Celani, see: Pupo, Regiane, et al. "A

Özkar, through her research and teaching at the Middle East Technical University, Istanbul Technical University and Massachusetts Institute of Technology, has significantly contributed in basic design education by using shape grammars as the foundation for design creation, reflection and computation.[94]

By incorporating shape grammar theory, pedagogy and formalism into the teaching of design, I explore sensory-perceptual and aesthetic education in design classes and studios. Shape grammars provide a formal framework into which we can continually plug in our sensory-perceptual and aesthetic experiences. We can capture our momentary visual reasonings in the form of shapes and shape rules. Design is practiced by continual practice with embedding, writing rules, composing with shapes, and evaluating forms. It also entails familiarity with our idiosyncratic ways of embedding and navigating in visual rule and schema applications in generating designs, grammars and computations.

2.5 Continuing the Pedagogical Vision

Today, the design studio milieu is still highly reminiscent of the Beaux-Arts setting. The primary method of learning in design school continues to take place in the active hands-on *doing* appointed by the studio, and the primary method of instruction in the conversational criticism termed the *critique*, or in short, *the crit.* Theoretical and practical knowledge is still studied in lectures and classes, but the heaviest credit is awarded to the design studio each academic term. Respectively, students select or are assigned to different design studios *(ateliers)*; ranging at levels from beginner to advanced, directed and taught by different groups of instructors or mentors acknowledged as *experts (masters or patrons).* Studios are often guided by instructors' particular teaching approaches and styles along with occasional guest critics who are other academics or practitioners in the field *(juries).* In the generation of designs, students commonly utilize media like tracing paper and paper that enable the quick capturing of ideas by sketching, line drawing, drafting, making and modelling *(esquisse).* It is also customary that peers help each other and seniors *(anciens)* guide younger classes directly providing feedback or by exemplifying stages toward and of expertise.

Design education, organized principally around these mentor-apprentice relationships among many actors, offers stimulating educational settings for active observation and participation. Studio curricula structurally facilitate criticism and evaluation in the form of desk critiques, pin-ups, interim reviews and final reviews. Studio subcultures also facilitate continual conversation and feedback among peers, groups, and classes. In addition to evaluations of personal work and progress, students learn from others by giving and receiving criticism in the social environment of the studio. Observing, receiving and providing constructive and meaningful criticism constitute an essential skill that designers apply – and persistently cultivate – for a lifetime.

Both the doing and the critique are principally aimed at externalizing and demonstrating what expert designers' *experiencing* and *reasoning* could be; even more importantly, it is aimed at externalizing

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Design Teaching Method Using Shape Grammars." *Proceedings of the 7th International Conference on Graphics Engineering for Arts and Design* (2007): 1 – 10. Also see: Duarte, Jose P. "MIT-Miyagi 2002: An Experiment in Using Grammars for Remote Collaboration." (pp. 79 – 115.) In *Collaborative Design and Learning.* Edited by Bento, J., Duarte, J., Heitor, M. and Mitchell, W. J. Westport, CT: Praeger Publishers, 2004. For applications in the architectural projects, see: Economou, Athanassios. "Shape Grammars in the Architectural Design Studio." *Proceeding of the 2000 ACSA Technology Conference.* Hong Kong, 2000. pp. 75 – 81.

[94] Steinø, Nicolai and Mine Özkar. (Ed.s.) *Shaping Design Teaching: Explorations into the Teaching of Form.* Aalborg, Denmark: Aalborg University Press, 2012.

and describing students' own experiencing and reasoning in the creative design process. Of the many conversations, the most valuable are indeed the conversations that students have with themselves, which I refer to as *self-conversation* here, for they formulate and give form to reasoning and procedural thinking of unique character. The studio acts as a social catalyst for how individuals reflect and create, receive feedback on what they do, ask the right questions in problem settings, and develop particular heuristics in design; which is ultimately in the service of cultivating self- conversation. Research shows that reflective critical thinking is integral to acquiring proficiency in design and professional knowledge.[95]

In my surveys and investigations in the education of design skills, sensory-perception, aesthetics and design creativity, I have identified four fundamental philosophical issues in a dialectic manner, issues which I believe repeatedly transpire in the ways design is theorized, applied and taught in design studios today: ***1) Parts versus Stuff:*** the problem of designers employing pre-determined parts, kits and frameworks, as opposed to designers allowing a fluent and dynamic approach to design elements and principles; ***2) Beginner versus Experienced:*** the problem of designers feeling they must adopt a beginner's mindset about design, as opposed to designers utilizing their prior knowledge, experience and culture; ***3) Shifting versus Consistent:*** the problem of designers maintaining consistency in the design process, as opposed to designers allowing themselves to change their minds as they go along; ***4) Embodied versus Disembodied:*** the problem of designers' being in the immediate sensory, perceptual and emotional space, as opposed to designers operating with after-the fact constructions, descriptions and abstractions.

I believe these four dialectics capture the objectives of many design exercises that we have come to know today. These four dialectics also underlie many of the intellectual and pedagogical ideas that are captured in this dissertation. The classification has been produced through the lens of shape grammar thinking and computational theory of design as described by shape grammars. To clarify, my purpose here is not to establish absolute right or wrong approaches to design teaching or learning. My purpose is to understand the pedagogical goals and tools better, while exploring their limitations, constraints, sequences and investigating new opportunities they suggest.

I have utilized this guideline in order to understand existing exercises and traditional instruction better; even more importantly, I utilize these four dialectics as implicit guidelines in elaborating on the pedagogical moments and goals of exercises that are discussed in the following sections through the lens of shape grammars. I also continue to use these dialectics in order to steer my conversations in the design studio toward the contextually more generous moments, towards seeing and doing in a free manner.

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[95] In his study on education and professional practice, Donald Schön coined the term "reflection-in-action" that points at the almost improvisational reflective practices of designers as they converse with their designs. Schön, Donald A. *The Reflective Practitioner: How Professionals Think in Action.* New York: Basic Books, 1983. Also see: Schön, Donald A. *Educating the Reflective Practitioner.* San Francisco: Jossey-Bass, 1987.

1) **Parts** *versus* **Stuff**	a) Designing with pre-determined parts, kits and frameworks. ($i = 0$.) *versus* b) Allowing a fluent and dynamic approach to design elements and principles. ($i \geq 0$.)
2) **Beginner** *versus* **Experienced**	a) Adopting a beginner's mindset about design. *versus* b) Utilizing prior knowledge, pre-conceptions, experience and culture.
3) **Shifting** *versus* **Consistent**	a) Allowing one to change their mind as they go along. *versus* b) Maintaining one's consistency in the design process.
4) **Embodied** *versus* **Disembodied**	a) Being in the immediate sensory, perceptual and emotional space. *versus* b) Operating with after-the fact constructions, descriptions and abstractions.

Figure 1. Some dialectic attitudes in design education and design pedagogy, that are studied through the lens of shape grammatical thinking and computational theory of design.

Particular design exercises targeting basic sensory perceptual skills have capitalized on combinatorial play that includes pre-determined parts and kits, such as Montessori's sensory kits, Froebel's gifts and occupations, and other kit-of-parts approaches argued by more recent designers like John Hejduk at the University of Texas. These exercises develop design skills in constrained design exploration environments. This approach is useful for having step-by-step pedagogical programs dictated by kits and aiding students in self-driven development. They are also highly effective in explaining how local design decisions change global results -- for instance, how given the same two basic units, different spatial relationships can lead to very different designs. Although these kinds of exercises are useful for combinatorial and finite play, the educational point should quickly be made that creativity and originality in design may also rest on continually seeing new shapes and repeated embedding. A fluent and dynamic approach to design elements through embedding constitutes a sensory perceptual and aesthetic foundation of creative design.

Similarly, some design educators have argued that our prior knowledge, pre-conceptions, experience and culture may be imposing pre-conceived, standardizing or normative frameworks onto the ways we perceive and act, hence hampering our creativity. Conversely, others have argued that prior experience can be utilized as scaffolding in order to build new knowledge of design. The first suggestion, which was clearly stated at the Bauhaus for design education, argued that students' minds should be seen as *tabula rasa* (empty slate) and that they should first be *de-schooled*, cleaned of their pre-conceptions, falling into the Lockean empiricist paradigm. This kind of *cleansing* was seen necessary in order for students to build their knowledge from a clean base, inspiring the articulation of the renowned "fundamentals" or the "foundations" course of the Bauhaus curriculum. While many modernist or minimalist theories argued for "decontamination," teaching and learning sciences have recently emphasized the importance of scaffolding in teaching and learning. The most important point here for us is the development of sensory perceptual skills and aesthetic appreciation though the design sequences and heuristics that an individual builds over time, moving from beginner to experienced designer. Nevertheless, whenever the scaffolding becomes too restrictive, students and instructors should be able to revert back to adopting a beginner's mindset about design. The best way to do that is to ask what we see and follow our eyes.

Staying constantly in touch with our immediate sensory-perceptions and emotions would assuredly guide us in a creative and original direction whenever we feel lost. This embodied state, nonetheless, can also benefit from our disembodied state, when we operate with after-the-fact constructions, descriptions and abstractions. Seeing and formalizing seeing often work in this dynamic. Capturing after-the-fact results of seeing in the form of constructions, descriptions and abstractions can inspire us in new ways. Practicing with formalisms in the disembodied, non-sensory space can be useful, but always in conjunction with the embodied state. The real rigor in creative design is not in its formalism, but in how we see and act on seeing. In relation to this, describing potential processes and sequences for ourselves in order to move our design processes along would yield productive results. We can force ourselves to keep our consistency in the design process by adhering to visual rules and explore designs within a specific design space. Or, we can move liberally and allow ourselves to change our minds as we go along, inventing new rules and schemas with which to explore diverse design spaces.[96]

Delight is in distress; in the current educational paradigm, we have lost the motivation and means to talk about aesthetic experience and sensory-perception as a key value. One of the reasons for this may be the unsettling and unnerving feelings associated with the ambiguity and plurality of seeing and doing. Designers work in open-ended, ambiguous and ill-defined processes, which can be especially distressing for beginner designers. However, the open-endedness and ambiguity of human perception should be seen as allies, not adversaries, as we pursue creativity, originality and imagination.

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[96] For generative examples that rely on consistency, see: Alexander, Christopher. *A Pattern Language: Towns, Buildings, Construction.* Sara Ishikawa, Murray Silverstein, with Max Jacobson, Ingrid Fiksdahl-King, Shlomo Angel. New York: Oxford University Press, 1977. Also see: Alexander, Christopher. *Notes on the Synthesis of Form.* Cambridge, Harvard University Press, 1964.

3 Practicing with Shape Grammars in Basic Creative Visual Design

Design exercises in modern fundamental design education often target the development of basic skills, centering on improvement in visual and spatial understanding through basic design elements and design principles. In order to constrain the form-related and representation-related intricacy, basic design exercises often feature elementary abstract shapes and forms. Design projects in the fundamental studios commonly begin with visually uncomplicated designs like simple black-white regular patterns, gradually increasing in intricacy, then arrive at more complex three-dimensional, colorful and textural compositions. Basic design exercises are moderated in difficulty regarding design constituents (parts), manipulations, operations, constituent properties and the intricacy of final designs (wholes).

It took great effort for modern theorists, particularly in art, design and the teaching sciences in the nineteenth and twentieth centuries, to challenge outdated art and design instruction in order to solidify modern design instruction focused on abstract form and visual principles. However, as studied in the previous chapter, deeply-rooted philosophical and pedagogical issues continued to re-surface. Ultimately modern design and drawing instruction became commonplace in higher education, even finding its place in k-12 curricula; nevertheless, the underlying theoretical and practical issues still remain alive today in the contemporary design studios, especially at schools of architecture and design.

To reiterate, some of the issues that we currently face as students and instructors in the current design studio start with the Cartesian duality imposed on holistic human reasoning.[97] The beliefs that art and mathematics – hence computation – or sensation and reasoning are incompatible need to be constantly challenged. The tendency to assume absolutist, objective, logical positivist or normative stances and beliefs in eternal fixed truths must be confronted. Extensive reliance on pre-fixing visual "parts," or "primitives," their combinatorics and pre-quantifying should be countered with the instability of visual form, open-endedness of making and the non-combinatorial nature of creation. By focusing on our particular and fluid sensory-perceptions in visual exercises, attention can be brought back to the pluralistic, ambiguous, idiosyncratic and subjective nature of empirical human experience. Our creativity is indeed critically ensured in this diversity, plurality and uncertainty. The "primitives" that many take for granted (as fixed) are themselves shifting as we build upon them!

In order to answer the need for *systematically* and *rigorously* educating human creativity and imagination in visual design, numerous design theories and methods have been developed. Out of those that argued that these essential skills can be educated, however, few have directly and fundamentally targeted the systematic, individual-driven and experiential-pragmatic education of sensory-perception and action. Even fewer have determinedly addressed the much needed instability, uncertainty and ambiguity that make "creative" seeing possible. Developed in the 1970s, shape grammar theory and formalism have offered a rigorous program for this pedagogical goal, building on imperative notions such as self- and process-driven "seeing," "embedding," "visual rules," "visual/spatial relationships," "visual schemas" and "design" as a systematic process of "visual computation" that operates on these basics.

[97] For instance, William James described the "whole" person in terms of "intellect, will, taste and passion." James, William. *The Sentiment of Rationality.* New York: Longmans, Green and Co., 1905.

Following the theoretical and pedagogical approach of shape grammars, the two fundamental creative activities of visual design as visual computation, seeing and doing, should be explicitly addressed in the design studio today. Contributions by Dow, Ross, *Bauhaus* and *VKhUTEMAS* among many others – already act as early inspirations for theorists and researchers who are interested in topics like "educating the eye," "the education of vision," or more broadly "visual education," especially in the context of procedural or step-by-step settings that build on each other.

Shape grammar theory emphasize the eye and the education of the eye through its focus on seeing: seeing as perpetual step-by-step aesthetic experiences and creative action. In this way, shape grammars emphasize an action-based approach to creativity through "seeing" and "doing." While shape grammars address crucial points like calculating visually with shapes – as opposed to calculating symbolically with atoms – its formalism allows us to construct formalized statements that pragmatically build on our dynamic phenomenological and aesthetic experiences. Seeing and doing can be methodically educated through a guided progression of design exercise and directed conversations in design critiques using shape grammars as the supporting framework. Additionally, following the shape grammar framework, students can gradually become self-directing in their learning processes.

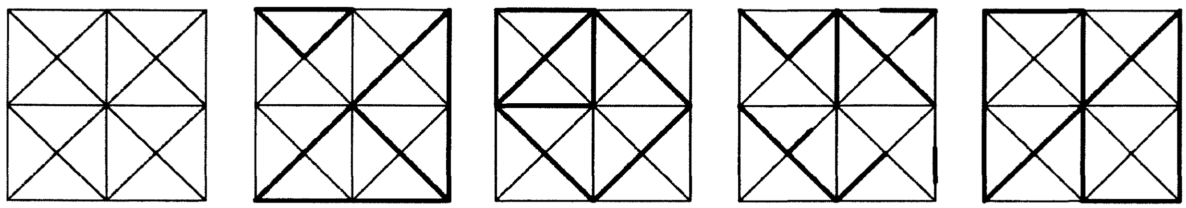
3.1 Visual Shapes, Embedding, Rules and Schemas

Shape grammars identify the fundamental elements of art and design concisely as *shapes*, a group of entities comprised of points, lines, planes and solids. Shapes are the basic visual material in shape grammars that we choose and work with when we are engaged in visual design activity. Shape grammars visually or spatially operate on shapes by utilizing functions described by *shape rules* or *shape schemas*. Shape rules in their basic form are written as $A \rightarrow B$. The left hand side of the rule takes the assignments of shapes that are based on *seeing*; the arrow defines the *application*; and the right hand side of the rule replaces the left hand side of the rule as a result of the rule application. By utilizing visual rules, we can analyze existing designs or generatively create new designs. When we can describe visual design activity with visual functions (rules, schemas) that operate on visual content (shapes), then, we can describe design as *visual (sensory) computation.*

As established by the shape grammar theory, visual computation processes rest on these two fundamental functions or operations, "seeing" (visual reasoning) and "doing:" discerning and articulating individual shapes that we wish to work with, and inventing functions in order to change them and create new shapes, forms and compositions. Given visual material – pictures, ornaments, paintings, sculptures, buildings, natural scenes – seeing can be described in the form of embedding and discerning particular shapes in the visual world. The idea of embedding is nicely articulated by the American philosopher and psychologist William James (1890) in his *Principles of Psychology*, as he laid out the notion of "sagacity" as a fundamental part of human reasoning. Given that S is a whole in the form of a bundle of information in the world, and M is part of that whole that we pull out, James describes human reasoning in two parts: "First, sagacity, or the ability to discover what part, M, lies embedded in the whole S which is before him; [s]econd, learning, or the ability to recall promptly M's consequences, concomitants, or implications."[98]

[98] James, William. "Chapter XXII: Reasoning." In *The Principles of Psychology*. Cambridge, Mass.: Harvard University Press, 1981. pp. 952 – 993.

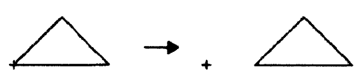
Following this philosophical insight, Stiny similarly emphasizes embedding as a fundamental part of creative visual thinking. *Object-based* seeing dissolves with embedding and we become free to choose any visual "part" (i = 0) from the visual "stuff" (i ≥ 0) in front of us. In fact, the creativity and originality of visual designs emerge once multiple people look at one shape, or, when one person looks at one shape at different times, or through different eyes. Challenging ourselves and our students to playfully engage in seeing different parts – doing different embeddings – and taking advantage of the plurality of ways of seeing, can be one of the first steps to teach and learn. Given the first shape (2.a) below, we can embed endlessly differing shapes in it. Each constitutes a new sight and insight:



(a, b, c, d, e)

Figure 2. Given the visual material – drawing 2.a – we can embed endless shapes, such as triangles (2.b), squares (2.c), lines (2.d), quadrilaterals (2.e). We discover parts *(M)* that are embedded in the whole *(S)*. The darker lines are intended to highlight the embedded shapes, they are not weighted lines.

Given the visual material, we can embed endless shapes: various triangles, squares, lines, or quadrilaterals among infinite possibilities. The darker lines in the drawings – here and in the following examples– are incorporated in order to highlight the embedded shapes. In the format of visual rules, $A \rightarrow B$, visual computation rests on continual embedding and rule applications. The discovery of parts A in the composition C is the fundamental step for the computations and designs we create. For instance, in the above example, I run through a design computation based on my embedding of triangles as in *4b*. By writing a rule that manipulates triangles, we also discern an action based on our sensory-perception, like translation:



Using the visual rule, I run the following visual computation:

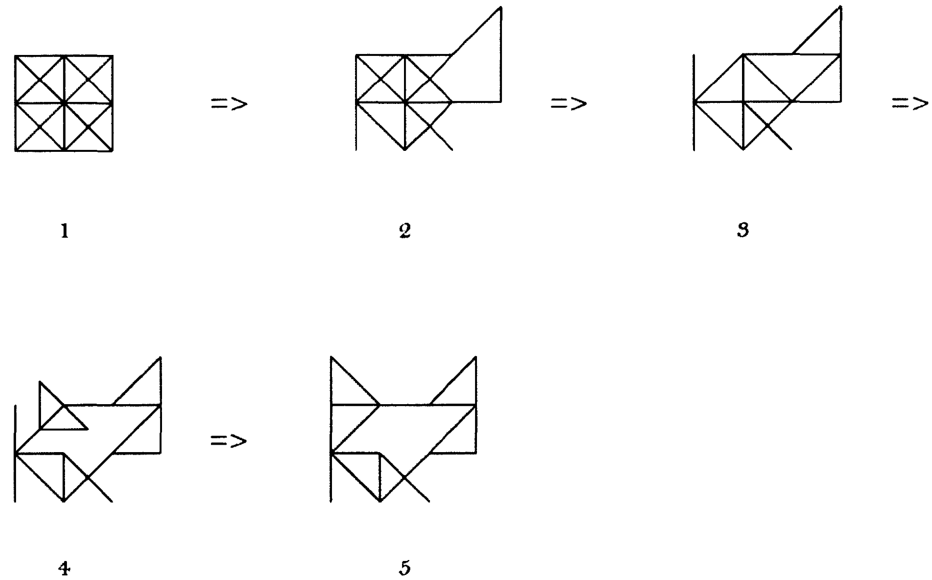
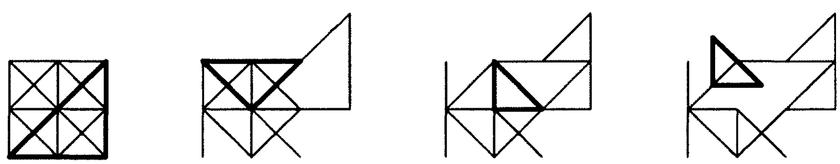


Figure 3. A computational visual design process. By writing visual rules that manipulate shapes, discerned based on embedding and identities, we also discern an action based on our sensory-perception.

In each step, I was embedding and applying my visual rule to a part. In each step, these parts were:



When we start as beginner designers, we learn how to operate and handle design processes; we learn how to embed, how to take action based on our sensory-perceptions, and visually evaluate emerging designs. Over time, as we become more experienced, we improve our understanding about our design sequences, processes and heuristics. We capture the results of our embeddings (seeing) with visual rules. We also capture our decisions, visual reasoning and actions with visual rules and visual sequences. The more we perform seeing, embedding, write visual rules, explore visual relationships and execute visual design and computations, the more we achieve insight about seeing and doing in design in terms of these fundamental activities. Shape grammars and shape grammar-inspired exercises can aid beginner designers, especially, in gaining these skills in a systematic way, by externalizing sensory-perceptual and aesthetic experiences and by offering ideas about *what next?*

Through shape grammars, we specifically seek to explain creative art and design not through imposed pictorial rules or design principles, but through the ways we see parts in wholes and the way we handle and act on those parts in order to perceive and generate new ensembles. Practicing with visual rules and visual computations has been wonderfully highlighted and explored in the last decades, as the pedagogical extensions and implications of shape grammars.[99] From these more specific definitions of shapes and visual rules, we also better understand the more generic descriptions of visual operations in the form of *visual schemas*.[100] Deriving from the more specific visual rules, visual schemas are the more generic descriptions of the kinds of operations that we perform in visual sensory perception and thinking. Visual rules are the specific operations that are written in the visual format; visual schemas are the generic visual operations that group visual rules together based on their types.

Stiny has identified a number of visual schemas that lie at the core of visual design heuristics. Like shape rules, but this time assigned *variables* in the place of particular shapes, visual schemas are written in the format $x \rightarrow y$ in their unrestricted form. From this most general schema, we can go into more detailed descriptions of visual actions. From the more general to the more specific, visual schemas can be enumerated as such: *(a)* x → y: unrestricted rules, unrestricted algebras; *(b)* x → y: unrestricted rules, same algebra; *(c)* x → x': general transformation and parametric variation rules; *(d)* x → t*(x): linear transformation rules; *(e)* x → prt (x): part rules; *(f)* x → b(x): boundary rules *(g)* x → t(x): Euclidean transformation rules (like the one used in Figure 3); *(h)* x → ø: Erasing rules; *(i)* x → x: identity rules; and *(j)* ø → ø: empty rule.

In this chapter, I focus on the visual with three fundamental schemas and some inverses. These include the identity schema x → x used to embed and identify specific shapes that we see, the part schema x → prt(x) and its inverse x → $prt^{-1}(x)$ used to pick out perceptual parts and wholes in our compositions, and the boundary schema x → b(x) and its inverse x → $b^{-1}(x)$.

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99 Knight, Terry. *Applications in Architectural Design, and Education and Practice.* (Report for the NSF/MIT Workshop on Shape Computation.) April, 1999. Reached at: http://www.shapegrammar.org/education.pdf
Also see: Özkar, Mine. *Uncertainties of Reason: Pragmatist Plurality in Basic Design Education.* Doctoral Dissertation, Department of Architecture. Massachusetts Institute of Technology, 2004.
100 Stiny, George. "What Rule(s) Should I Use?" *Nexus Network Journal* 13 (2011) 15–47. DOI 10.1007/s0000 4-011-0056-6; published online 25 February 2011. Also see: Stiny, George. "The Critic as Artist: Oscar Wilde's Prolegomena to Shape Grammars." *Nexus Network Journal* 17.3 (2015): 723-758.

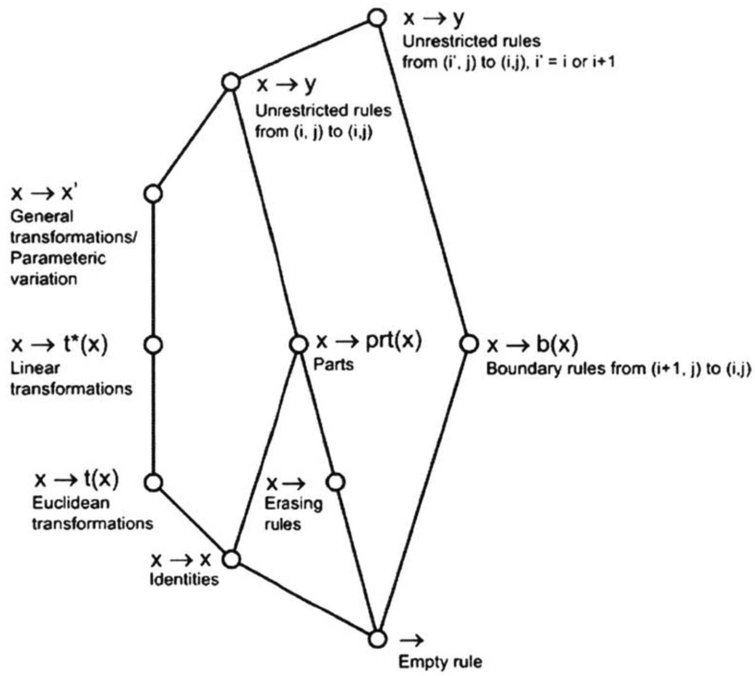

Figure 4. Stiny's lattice of schemas (2011) hierarchically describes them. Complex schemas that are more general can also be explained in terms of the more basic ones below them.

Shape grammars offer us visual schemas as heuristic tools that are indeed very intuitive to employ. We most likely already perform these sensory and perceptual actions when we look at the world and when we design. Here, I define aesthetic experience in terms of the practices of embedding in the sensory perceptual (visual) world and computationally creating based off of seeing and embedding, and aesthetic and design education as the continual practice of embedding and creating computationally.[101]

By the utilization of visual schemas, designers can capture and materialize their basic yet essential experiences and aesthetic encounters with the world. Even with the most basic visual schemas, these encounters can become the material of and for visual design. Indeed, seeing is designing, and seeing entails particular and personal attitudes, too. For instance, seeing and capturing a visual experience with the identity schema $x \rightarrow x$ into a shape on paper is an act of designing. If designers wish to continue their creative process on the visual material, they can do so with further applications of visual schemas and their combinations and compositions, which can then take their designs to a more advanced and intricate state. Going from basic visual schemas towards more complex ones, this chapter primarily focuses on design explorations of the basic visual schemas, their combinations and compositions in generating new visual designs. Experimenting and practicing with visual schemas and algebraic operations is established as the educational methodology that guides seeing and designing, in other words, sensory perceptual, aesthetic and design education.

[101] Stiny, George. "Generating and Measuring Aesthetic Forms." In Carterette, E. C. and Friedman, M. P. (Ed.s.) *Handbook of Perception, Volume 10.* New York: Academic Press, 1978. pp. 133-152.

3.2 Practicing with Embedding and Basic Visual Schemas

Creative design events can be described with visual schemas, which are visual functions that operate on assigned shapes. The evolution of designs can be traced by a record of visual activities, steps that capture visual reasoning, sensory perceptions, thoughts and doings. Fundamental algebraic operations on shapes include addition and subtraction. Artists and designers continually perform these operations on visual shapes and forms while they design. When we see a shape or form, we also start contemplating – visually or intellectually – on the kinds of manipulations that could be performed on it. These manipulations can analogically be thought of as algebraic operations, such as adding shapes up or subtracting one shape from another. All shape operations can be described under general visual schemas that are studied by Stiny (2011; 2015) and sequences generated by individual designers during particular design processes.[102]

In service of the pedagogical goals to develop skills in embedding, combining, composing, and improvising in shape grammars, some of the fundamental visual schemas that are elaborated here include the identity schema $x \rightarrow x$ used to embed and identify specific shapes that we see, the part schema $x \rightarrow prt(x)$ and its inverse $x \rightarrow prt^{-1}(x)$ used to pick out perceptual parts and wholes in our compositions, and the boundary $x \rightarrow b(x)$ schema and its inverse $x \rightarrow b^{-1}(x)$ used to embed shapes in different shape algebras.

As Stiny (2011: 21) described in depth, fundamental visual schemas describe basic operations of visual reasoning. As design activities become more developed and complex, in order to describe them, all fundamental schemas can be combined in various ways in order to create schematic descriptions of the kinds of intricate operations that we do in art and design. Stiny has detailed various ways of utilizing schemas in creative design, as well as elaborating on two central ways of combining them, which are *by addition* and *by composition.* Adding up schemas works straightforwardly like adding up functions in mathematics, where the output is computed for a given input through a number of specific operations in a specific sequence. To give an example for the addition of schemas, given two hypothetical schematic functions $x \rightarrow e(x)$ and $x \rightarrow f(x)$, the function $x \rightarrow e(x)$ and $x \rightarrow f(x)$ can be added to obtain the addition $x \rightarrow e(x)+f(x)$. Composition by schemas works like functions in mathematics, too. For instance, given the same hypothetical schemas, in the composition $e(e(x))$, the result of $e(x)$ goes into the function $e(x)$, hence describing a recursive composition; or in $e(f(x))$, the result of $f(x)$ goes into the function of $e(x)$; and so on. Two examples are shown below with frequently utilized schemas in order to show combinations of schemas by addition and by composition.

$x \rightarrow x$	[Identity schema]
$x \rightarrow t(x)$	[Transformation schema]
+ ______________	
$x \rightarrow x + t(x)$	[Combining schemas by addition]

[102] Stiny, George. "What Rule(s) Should I Use?" *Nexus Network Journal* 13.1 (2011): 15-47. Also see: Stiny, George. "The Critic as Artist: Oscar Wilde's Prolegomena to Shape Grammars." *Nexus Network Journal* 17.3 (2015): 723-758. Visual schemas are also investigated by Özkar: Özkar, Mine. "Visual Schemas: Pragmatics of Design Learning in Foundations Studios." *Nexus Network Journal* 13.1 (2011): 113-130.

$$\frac{\begin{array}{l} x \rightarrow t(x) \\ x \rightarrow b(x) \end{array}}{x \rightarrow t(b(x))}$$

[Transformation schema]
[Boundary schema]
[Combining schemas by composition]

Figure 5. Combining schemas by addition and by composition.

Design students can benefit greatly from using visual rules and visual schemas while they improve their design abilities and produce design projects in the studio. Recording their design processes is shown to be a highly useful design method for design students. To better understand their own sensory perceptual activities, visual reasoning and design operations create the opportunity for learners to reflect on them. Externalization efforts eventually lead to more elaborate contemplation, and more importantly support students' self-conversation as well as bettering conversations in the social structure of the studio. The social aspect of the studio has targeted externalization with the right motives. However, as sometimes is the case, prematurely formalized designs or quickly generated projects for critiques that lack deep engagement are seldom educational or very imaginative. Externalizing sensory-perceptual thoughts is first and foremost for students themselves and to keep the conversations going on between them and their designs, to find steps that inspire them towards improved designs.

Another issue in studio discussions, which was touched upon in Chapter 2, is the belief that externalized thoughts, expressed opinions and outwardly shared ideas are often seen as carrying objectivity. Students often believe, misguidedly, that successful design projects have gone through particular sequences, or that successful designers employ specific methods, or that effective designers are in the possession of objective knowledge about seeing *correctly* or about aesthetic ratios and formulas. Students need to be reminded that there is no objective knowledge, only immediate experience and heuristics. Design is not based on know-what but know-how, not on objects but on experiential and intuitive heuristics in navigating the visual world. Similarly, students need to be continually reminded that studio discussions do not aim to transfer objective knowledge from those who have it to those who do not; reasoning, thoughts, opinions and ideas are temporarily formulated statements that arise within the space of the discussion.

Visual rules and visual schemas are helpful reminders that emphasize individual ways of seeing and doing, therefore empowering and liberating students as individual designers. The rule-based and schematic language of shape grammars can elevate the quality of studio communication and the relevance of these conversations to individual creative design processes. The ignored or avoided conversations on sensory perceptions and aesthetic experience can find their way back into design when students become capable of formulating and expressing their experiences and preferences computationally. The ability to formulate and articulate such experiences is one of the core objectives of design studio; practicing with visual schemas throughout design projects will develop this skill faster, educate students' eyes, and make them better designers who are in deep connection with their experiential world.

3.3 Practices with $x \rightarrow x$, $x \rightarrow t(x)$, $x \rightarrow x + t(x)$ and $x \rightarrow \Sigma\, t(x)$

After developing basic knowledge of visual schemas, students can start learning about more complex ways of working with visual schemas in order to deepen their understanding of visual reasoning, visual operations, visual manipulations, and how their designs can be described formally in terms of visual rules and visual schemas. For instance, one of the most commonly used visual schemas in art and design is $x \rightarrow x + t(x)$. As discussed in the previous chapter, this schema is produced by the addition of two basic visual schemas, the identity schema $x \rightarrow x$ and the transformation schema $x \rightarrow t(x)$. We firstly see and identify an x, and then we subject it to a Euclidean transformation and generate a design by the addition of the two. The fundamental transformation operations are Euclidean transformations that include translation, rotation, and reflection. As we go upwards in the schema lattice, the nature of transformations can become more general. For instance, with the schema $x \rightarrow t^*(x)$, linear transformations like scaling can be applied; with $x \rightarrow x'$, the geometric parameters of x can be altered as well.

In various objects of art and design, we observe that the visual schema $x \rightarrow x + t(x)$ and its more general formats have been employed in visual and spatial thinking. In classical architecture, $x \rightarrow x + t(x)$ is observed frequently in the creation of architectural plans and façades. It is employed to combine spaces and building elements in order to obtain architectural compositions, such as in the Palladian villa plans, or in the typologies of Quatremère de Quincy to organize spaces, walls, columns, doors and windows, and similarly in the dictionary of Viollet-Le-Duc.[103] In modern art and design, we find countless examples of visual schemas $x \rightarrow t^*(x)$ and $x \rightarrow x'$, compositions created by the recursive use of these schemas with lines and planes.[104] Numerous modern paintings clearly have the schema additions $x \rightarrow x + t^*(x)$ and $x \rightarrow x + x'$ as their underlying logic, applied repeatedly to basic shapes or forms. Artistic, designerly or architectural compositions can all be analyzed as compositions of visual schemas; artistic and designerly creative activity can be formalized and captured by visual schemas and the step-by-step computational design process.

Schema additions and compositions allow us to explain our visual reasoning, design moves and gestures in a simple and straightforward way. As we design visually, we can also capture visual schemas alongside visual designs. Students benefit greatly from this twofold activity: as they see, they describe; as they describe, they see. Visual processes and visual schemas work hand-in-hand in visual inspiration and allow students to move on if they feel stuck or inspire them with more interesting possibilities. As visual processes go on, accompanying visual schemas start to form and group. Additions and compositions are generated from simple schemas; groups of schemas form to express chunks of visual routines. Stiny (2011) has shown that basic schemas can be organized in lattices that again go from singular basic operations to more generic groups of operations, such as the *sums*:

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[103] Stiny, George and William J. Mitchell. "The Palladian Grammar." *Environment and Planning B* vol. 5, issue 1, June 1978: 5–18. Also see: Lavin, Sylvia. *Quatremère de Quincy and the Invention of a Modern Language of Architecture.* Cambridge, Mass. : MIT Press, 1992. On "rational" architecture, also see: Viollet-le-Duc, Eugène-Emmanuel. *The Foundations of Architecture: Selections from the Dictionnaire Raisonné.* Introduction by Barry Bergdoll; translation by Kenneth D. Whitehead. New York: G. Braziller, 1990.

[104] In modern architecture, planar elements like walls were organized to create flowing spaces. Different walls were subjected to different kinds of Euclidean and non-Euclidean transformations in order to create asymmetrical compositions. Based on their meaning in design, these planar elements were also treated differently in terms of building materials; in shape grammar terms, the elements had different weights. While some walls facing a particular sun orientation became marble covered walls, others became transparent surfaces. Horizontal planes became roofs, balconies or mirror-like pools.

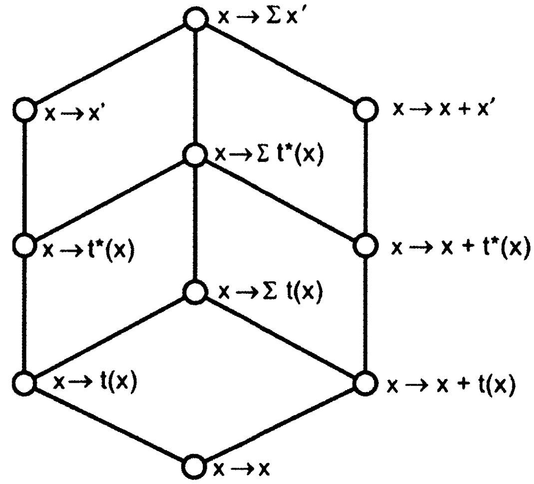


Figure 6. Stiny (2011) Lattice for identity relations, transformations and their sums. Similar to Stiny's lattice of schemas (2011), identity relations, transformations and sums are hierarchically described. Complex schemas that are more general can also be explained in terms of the more basic ones below them.

Based on our operations and routines, we can produce lattices of our own that correspond to our design processes and projects. We can also benefit from existing lattices to become inspired while we design. We can use a lattice such as the above to gauge pedagogical goals of design exercises. We can also employ them to write up new design exercises, which can be used to develop particular skills, such as improving skills in seeing new and diverse shapes in a design (embedding and practices with x → x and x → prt(x)), or practicing with basic operations on a perceived unit, or producing simple designs with dynamically perceived units. This chapter demonstrates such an effort.

After practicing with identity and transformation schemas, we can gradually move up to simple and gradually more complex sums. While we design, shorter descriptions for the combinations of schemas can be produced. Suppose we have multiple transformations of an x in our design that we would like to sum up:

$x \rightarrow t_1(x)$
$x \rightarrow t_2(x)$
$x \rightarrow t_3(x)$
$x \rightarrow t_4(x)$
...
$x \rightarrow t_{16}(x)$

This combination by addition schema can shortly be written as x → Σt(x). If we would like to further specify the number of copies, the schema can also be written as $x \rightarrow \sum_{i=1}^{n} t_i(x)$. With this schema, we can show the generation of a simple design that is a repeating pattern, for instance, created by the population of a regular grid with a unit. Once we have a unit x, then we can populate regular grids – such as 2 by 2, 3 by 3, 4 by 4, 3 by 5 – by the addition of multiple transformations of our x that are t(x)s, shortly utilizing the x → Σt(x) schema. Some of the instances of this schema are demonstrated:

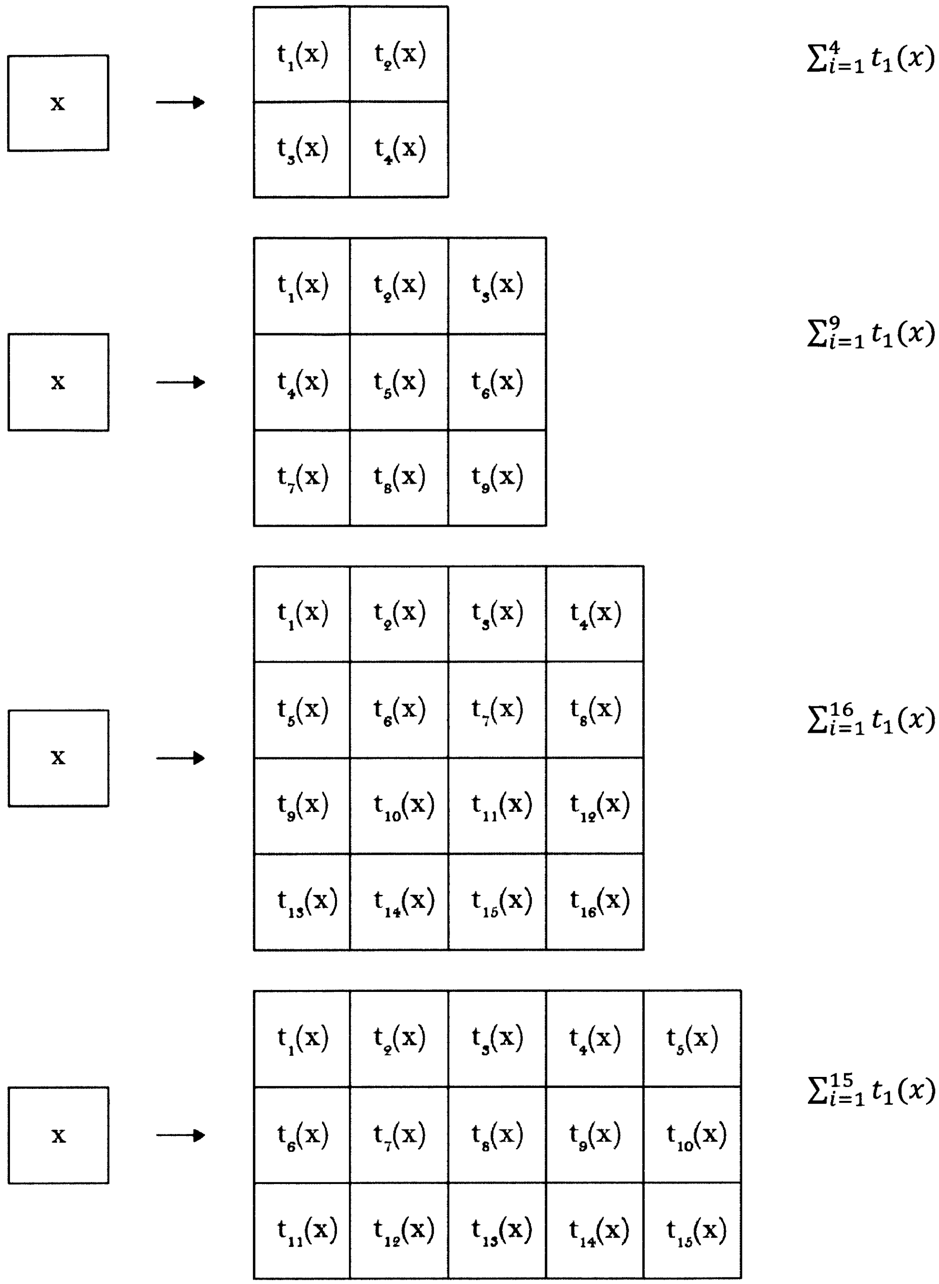
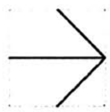
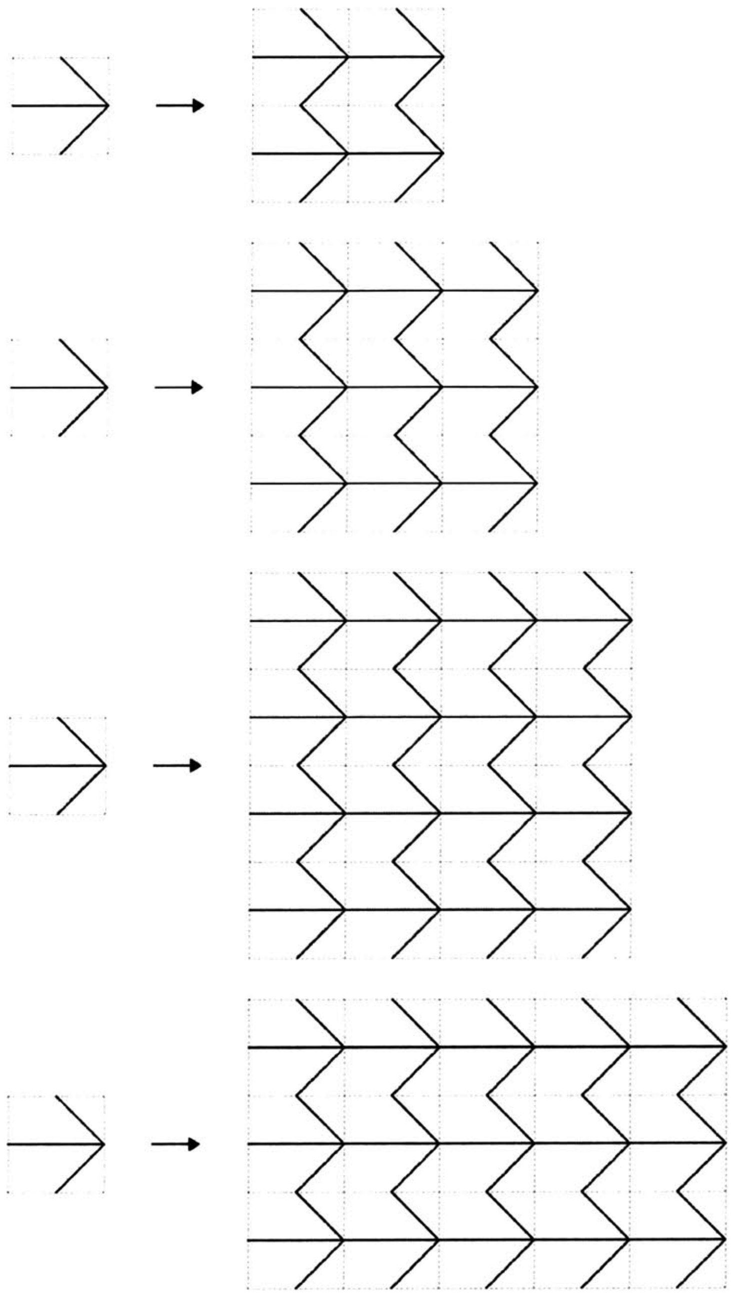


Figure 7. 7.a – 7.d: x ⟶ Σt(x) schema is demonstrated by instances of regular grids that are populated by the transformations t(x) of the unit x – 2 by 2, 3 by 3, 4 by 4 and 3 by 5.

As seen above, the specific number of transformations can be recorded in the detailed format of the schema as well, which is $\sum_{i=1}^{n} t_i(x)$. If we populate all the cells of the quadrilateral grid, for a 2 by 2 grid, we have the accompanying schema $\sum_{i=1}^{4} t_1(x)$; for a 3 by 3 grid, $\sum_{i=1}^{9} t_1(x)$; for a 4 by 4 grid, $\sum_{i=1}^{16} t_1(x)$; and for a 3 by 5 grid, $\sum_{i=1}^{15} t_1(x)$. In order to show a basic visual design now, which utilizes the schema x ⟶ Σt(x), let's suppose x is assigned a unit that is composed of three lines and looks like an arrow pointing to the right within a unit boundary (shown with the dashed lines):



Then, with the application of the schema x ⟶ Σt(x) on the exemplified regular grids, we obtain the following shape computations and designs.



n = 4

n = 9

n = 16

Figure 8. 8.a – 8.d *(top-down)*: Shape computations of different grids with the schema x ⟶ Σt(x).

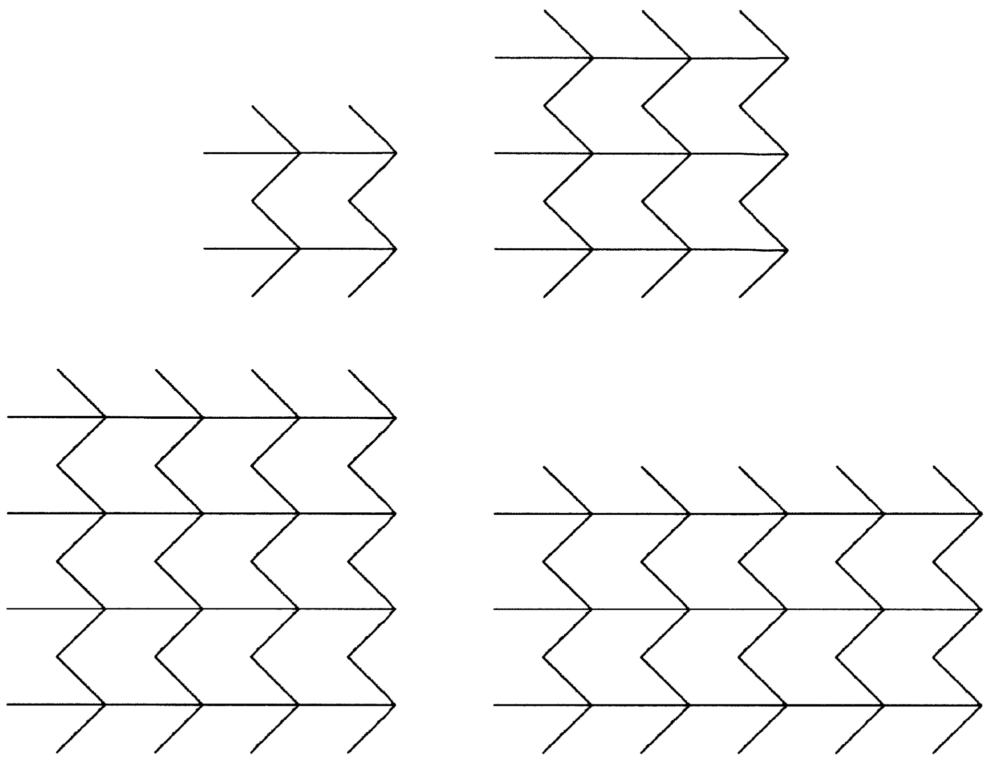


Figure 9. 9.a – 9.d *(from left to right)*: Designs generated by different shape computations using the schema $x \rightarrow \Sigma t(x)$.

As I generated these examples, a rather amusing question arose in my mind: should I go left or should I go right? My initial unit looked like an arrow telling me to go right. However, after I completed the shape computation, I began to also see chubby arrowheads telling me to go left. Indeed, I began to see these two kinds of arrowed patterns concurrently, as in a Gestalt switch. My eye now simultaneously picks out the skinny arrows, and then it picks out the chubby arrows. In fact, the more I look, the more I am reminded that seeing is pluralistic, not dualistic. I am drawn in to discover many interesting shapes, with the continual applications of $x \rightarrow prt(x)$ or $x \rightarrow x$ now: the zig-zag grid and structure, shapes that look like folded paper roofs, which are pointing rightwards, or pointing leftwards, short and long arrows of various kinds, Ss and Zs, Ms and Ns, Vs and 3s, and the list goes on. This kind of playful visual activity presents the perfect opportunity to educate seeing, the eye, visual contemplation and visual reasoning.

When I picked out the initial shape for my unit, I did not know that the shape computation was going to result in this simple yet interesting design with high perceptual ambiguity. These simple design exercises allow us to practice with small visual experiments that can have a big impact on our sensory perceptual and aesthetic education. For design students, design exercises that utilize the schema $x \rightarrow \Sigma t(x)$ provide straightforward *self-driven eyes-on, mind-on, hands-on* processes that allow them to explore designs and practice on their own.[105] They also act as helpful guidelines to follow in existing studio exercises – for instance, the "pattern" exercise that is part of all fundamental and basic design studios in design schools.

3.4 Generating New Designs and Describing Different Sums

The regular pattern exercise with the rectangular grid and line elements is an easy and straightforward way to start generating visual designs. As mentioned, even though the unit and the grid may be easy to handle and manipulate, students can quickly begin to obtain perceptually and schematically rich designs. Starting new design projects is more often than not frustrating for design students. Having a simple heuristic device such as the $x \rightarrow \Sigma\, t(x)$ schema is a very useful device to help them over this initial hurdle. Having designs in hand – even though very modest – allows conversations between students and instructors to start, even more importantly, provides students themselves with something to look at and see. From then on, students can converse with themselves or their instructors in order to advance their designs.

For the advancement of visual designs, one way to proceed is to begin disturbing perceived *regularity*, creating *disorder* and discovering *variety* in the rectangular grid, line elements and uniform population. One straightforward way to do this is to start populating the grid *irregularly*. For our simple 2x2 grid, instead of having all 4 cells occupied, we can omit one or two:

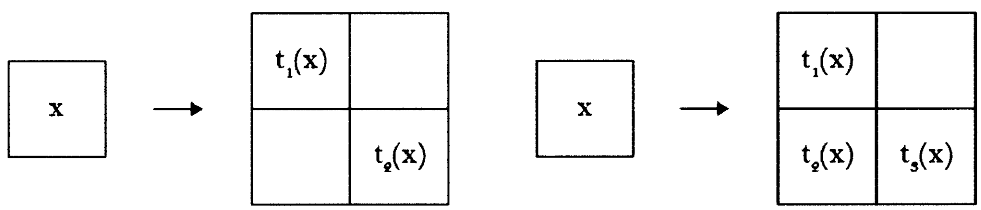
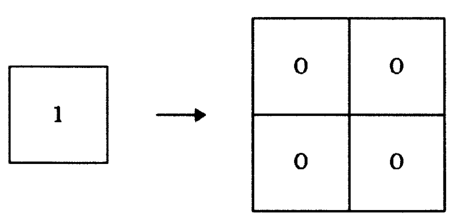


Figure 10. Discovering irregular grid populations with the schema $x \rightarrow \Sigma t_n(x)$ on a regular 2x2 rectangular grid.

Indeed, for the 2x2 grid, if one wishes to be exhaustive in exploring his or her entire design space, she can be thorough with it. The number of cells being *n*, we have n=2x2=4 number of cells for our 2x2 grid and 2^n designs in total, corresponding to 2^4=16 designs. For the defined kind of population, we can generate the finite list of these sixteen designs, featuring all the possible populations of the 2x2 grid with a unit:

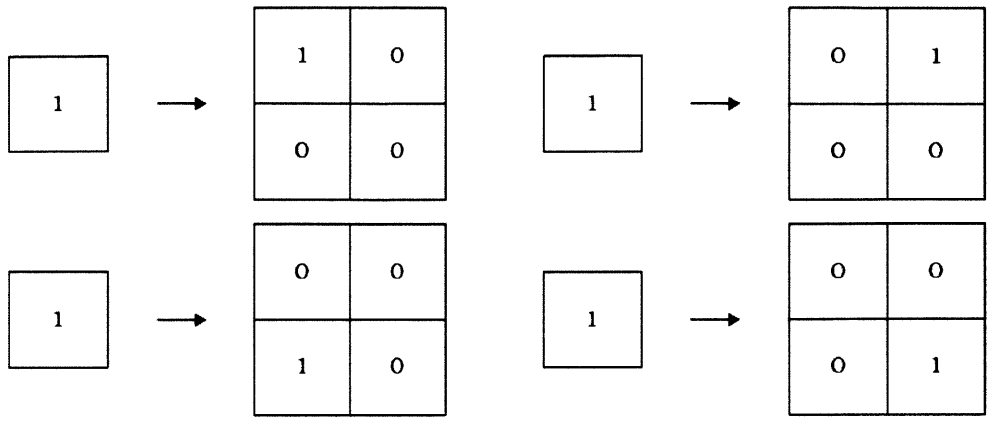
$$\sum_{i=1}^{0} 0(x)$$



(a)

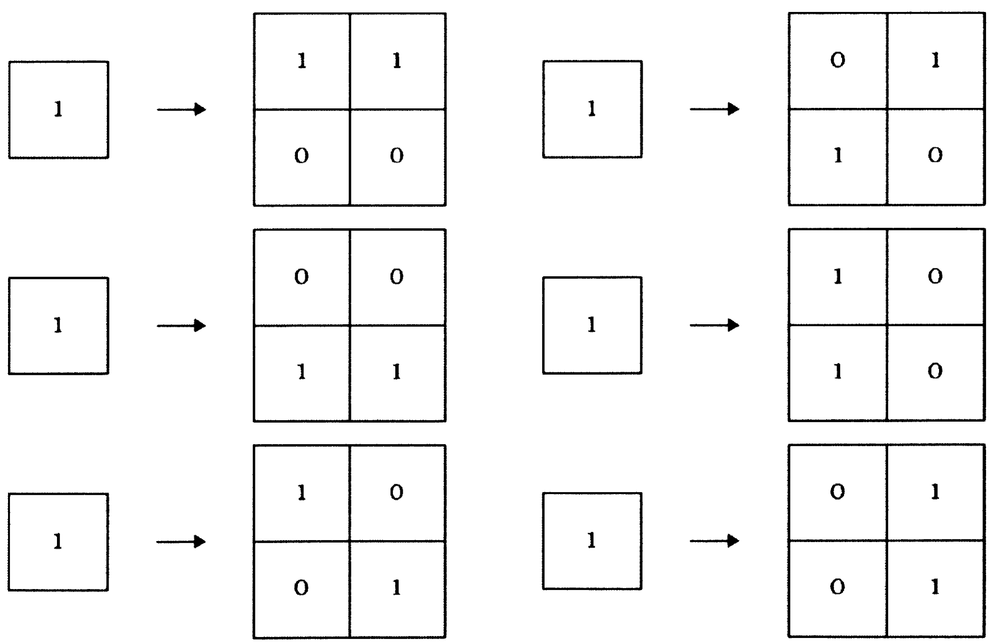
[105] The term "eyes-on" was introduced by Özkar in her dissertation: Özkar, Mine. *Uncertainties of Reason: Pragmatist Plurality in Basic Design Education.* Doctoral Dissertation, Massachusetts Institute of Technology, 2004.

$\sum_{i=1}^{1} t_1(x)$



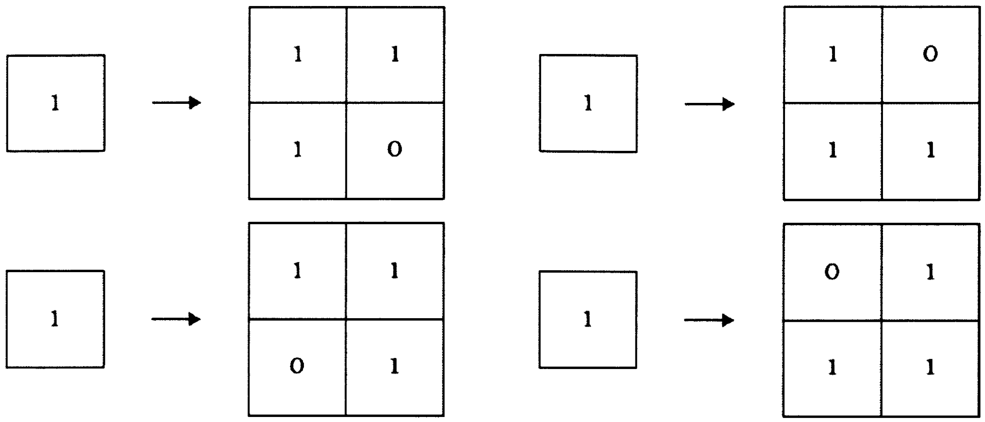
(b – e)

$\sum_{i=1}^{2} t_1(x)$



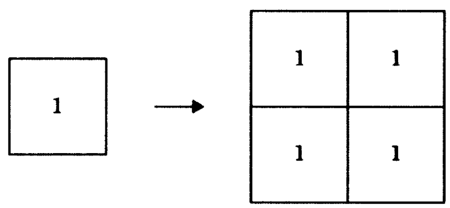
(f – k)

$\sum_{i=1}^{3} t_1(x)$



(l – o)

$\sum_{i=1}^{4} t_1(x)$



(p)

Figure 11. 11.a – 11.p: Given a population type, all the sixteen possible populations of the 2x2 rectangular grid is listed. Different populations can also be shown with different x ⟶ Σt(x).

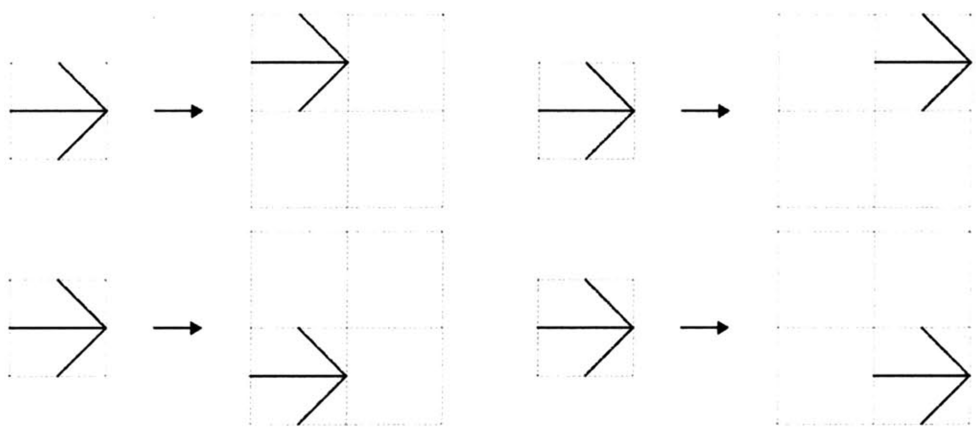
This type of *combinatorial play* or *finite play* encourages students to discover the logic and structure of the process of generating new designs and discovering design spaces. While visual schemas innovate the more free-flowing formalizations of highly dynamic and open-ended processes of seeing and doing, occasional combinatorial explorations can reintroduce control and constraints into the design process. Such play is also a useful way for students to begin contemplating the dynamics of design as a decision-making activity – how designers' particular decisions affect the course of design and the nature of design outcomes. At this point, it is crucial to highlight that if one would like to be exhaustive in this way, there exist mathematical and computational systems that can make this possible, such as shape grammar formalism. However, the main point to highlight is that such discrete, combinatorial and finite systems are only special cases of continuous, non-combinatorial and infinite systems. So, the ultimate goal is not to be exhaustive with schemas and designs; rather, it is to begin generating visual material and focusing on the visual qualities and possibilities of emerging designs. Nevertheless, the value of such combinatorial and finite exercises should also be acknowledged for allowing students to exercise self-imposed control and constraints, especially with relation to sensory and perceptual input.

Returning to our 2x2 grid; now, we may suspect that a 2x2 grid, irregularly populated, may not generate very rich designs or design processes. Nevertheless, even these basic schemas allow us to generate simple designs to talk about. Despite our initial pessimistic suspicion, let's generate some visual designs and consult our eye:

$$\sum_{i=1}^{0} 0(x)$$

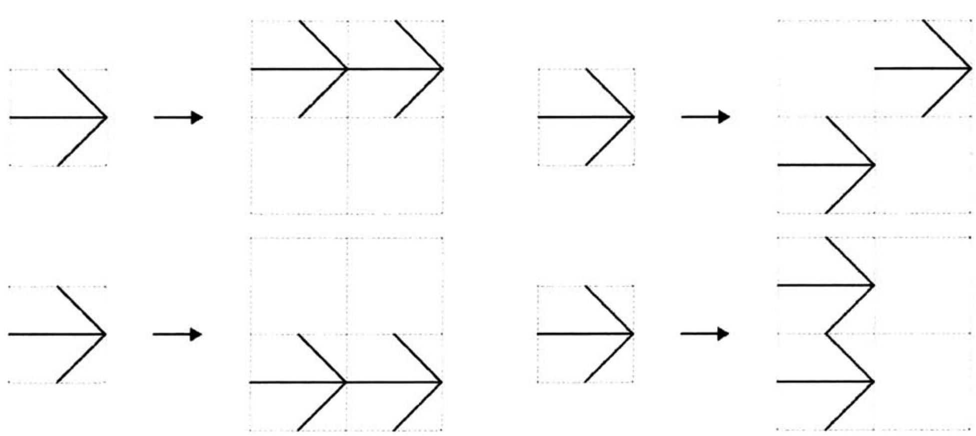
(a)

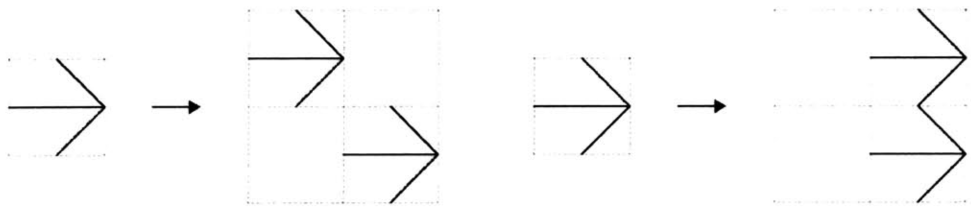
$$\sum_{i=1}^{1} t_1(x)$$



(b – e)

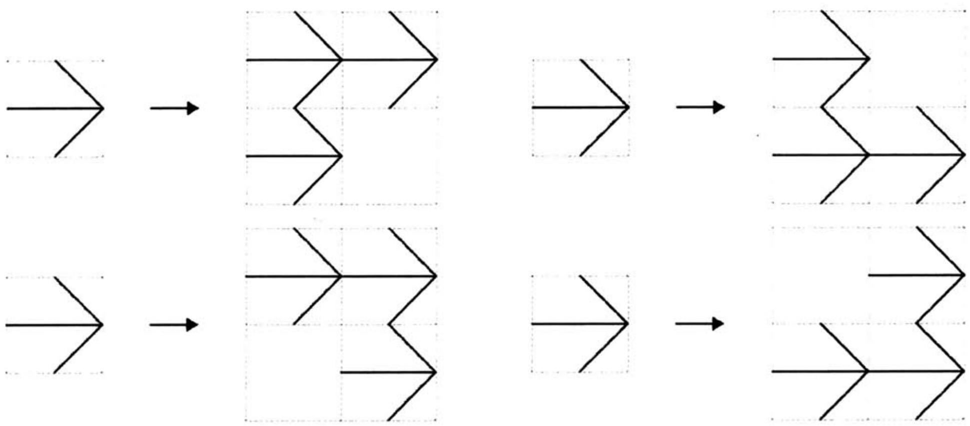
$$\sum_{i=1}^{2} t_1(x)$$





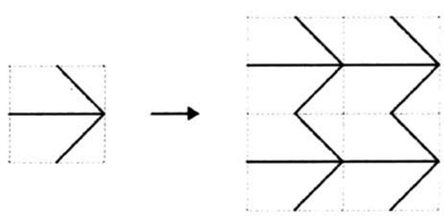
(f – k)

$$\sum_{i=1}^{3} t_1(x)$$



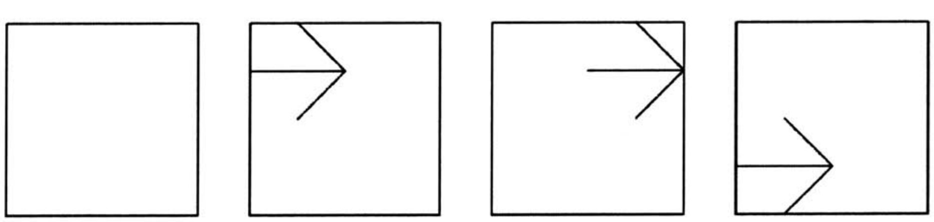
(l – o)

$$\sum_{i=1}^{4} t_1(x)$$



(p)

Figure 12. 12.a – 12.p: The computation of visual designs by irregular populations of the rectangular grid utilizing $x \rightarrow \Sigma\, t_n(x)$.



(a, b, c, d)

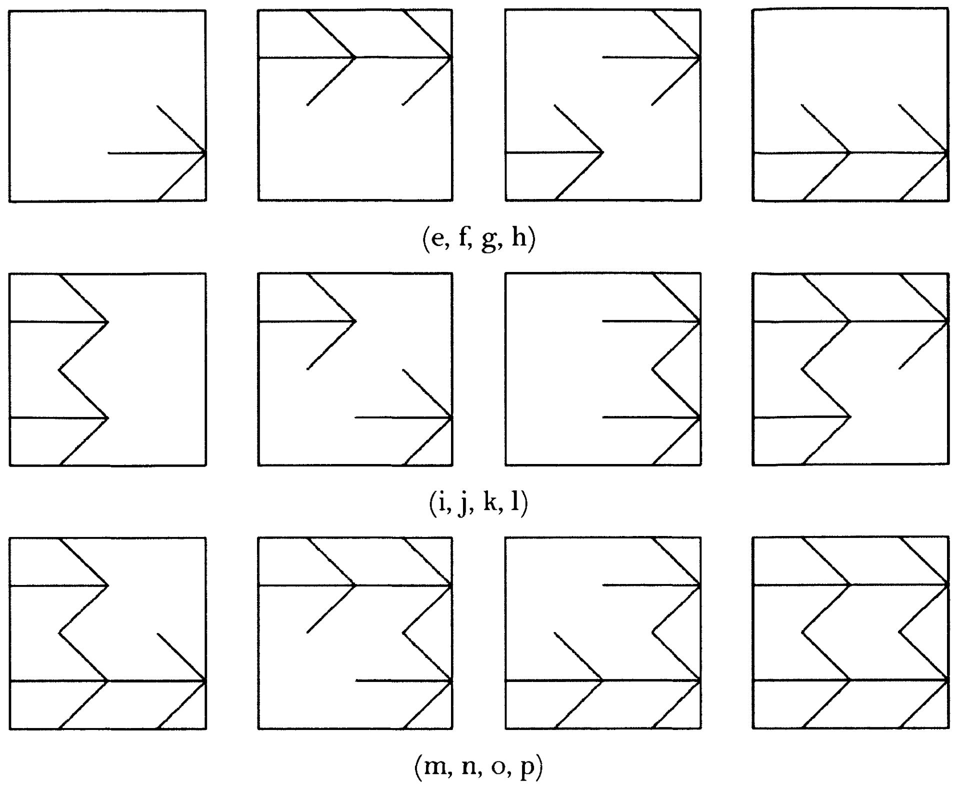


Figure 13. 13.a – 13.p: The design space for x ⟶ Σ $t_n(x)$ for a 2x2 grid, on a 2x2 sized canvas.

Generating these designs is easy and straightforward with the schema x ⟶ Σ t(x). Yet even while I was drawing, I began to see many new shapes and design possibilities for the next move. As I survey these designs, different ones inspire me to take different steps. I also discover that given the same canvas for these designs – out of the 2x2 grid – we can start to discover different relationships of the parts to whole. The pictorial plane and the shape or boundaries of the canvas are also assumed as part of the visual organization. The particular placement of shapes and forms on the canvas leads to different emergent shapes.

An important aspect of such an exercise is that it helps students to note how emergence is produced and how this emergence encourages their idiosyncratic ways of embedding. Some instances from the design space as I exercise embedding include: in 13.b, 13.c, 13.d, 13.e, as the arrows are placed in the corner of the canvas, I embed a quadrilaterals and a small triangle. In 13.f, 13.h, I embed two different quadrilaterals and a small triangle. Also, my eye completes the arrow arm pointing toward the lower left, until it meets the edge of the canvas. I would like to see two triangles of different sizes in the next step. In 13.g – 13.h, my eye does a similar *enclosing* or *encircling* move at the very center of the canvas to complete the lines and produce a quadrilateral. As I do that in 13.j, I immediately see a large triangle on the top right and a roughly L-shaped polygon in the lower left. In a similar fashion, 13.i inspires me to create a square at the center. For some reason, 13.k appears boring. My embedding suddenly becomes very rich in 13.l, 13.m, 13.n, 13.o; I observe a higher number of lines with a good balance and distribution of white space generates so many new possibilities. Yet, 13.p suddenly becomes more boring too, and start to suspect too many and too regularly enclosed shapes may need an opening kind of operation next.[106]

These initial embedding insights are immensely valuable for design students. They can record how they think visually using visual rules; they can also write accompanying visual schemas on how they came up with particular operations, as well as capture inspirations for the next step, as I have done above verbally. It is important to keep a visual track of embeddings, perceptions and thoughts because these may change as rapidly as they are created. Several days ago, I was inspired one way by a set of designs; today I see other shapes and possibilities. As I contemplate the possible next steps, this context also has an effect on what and how I see them. William James (1981[1890]) himself noted that sagacity is molded by our present "practical and aesthetic interests."[107]

As I begin to actually draw designs, my perceptions and thoughts begin to dynamically reorganize as well. I am now going to follow some of the inspirations above and produce some drawings. In 13.e, I see a small triangle at the bottom right. As the first of the two further steps, I would like to enclose the arrow-like shape into a square shape standing on its corner; secondly, I would like to explore what happens if I can form a large triangle on its edge by tracing the top two lines. As I took these steps, the process unfolded as the following computation:

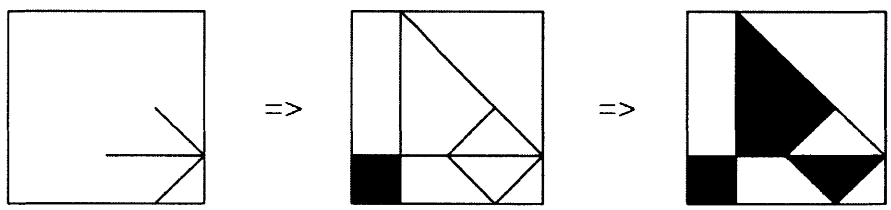


Figure 14. New design based on 13.e.

13.g inspired me to create a quadrilateral at the center, and then test how I might be able to divide the L-shaped polygon.

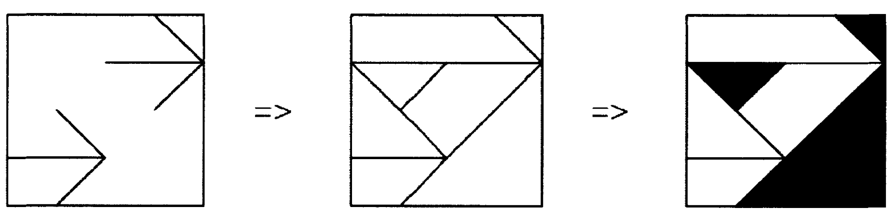


Figure 15. New design based on 13.g.

Yet another interesting lesson appears here: when I followed my initial inspirations based on the visual stimuli and creative seeing, I produced a batch of drawings. 13.g initially inspired me to explore the notion of *repetition* because I had perceived various small squares and wanted to experiment with those, which led to the following computation:

---

[106] Also note that *26.a* looks like the erasing rule (x ⟶ ø); *26.b* – *26.e* looks like a transformation (translation here) of x, different x ⟶ t(x).

[107] Pawelski, James O. *The Dynamic Individualism of William James*. Albany, NY: State University of New York Press, 2007.

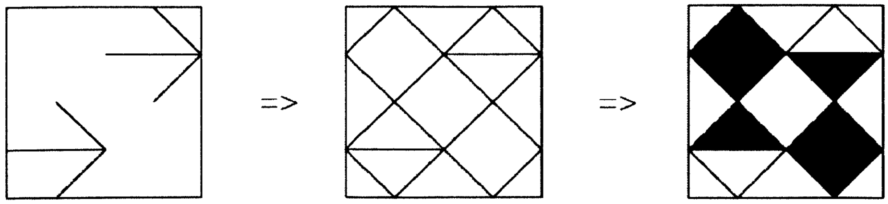


Figure 16. New design based on 13.g.

Seeing is dynamic in this way, too: based on the same stimuli, our perceptions may change. Our embeddings change. Just as different people construct different perceptions out of the same input, the same individual on different days can see and embed in a different way. In fact, the originality of our designs comes out of these diverse and inventive participations with visual material, even though it is the same physical input. Keeping a record of our seeing and embedding with visual rules and visual schemas is valuable in evaluating designs, improving our judgment skills and creating more material through the doing. The same dynamism also occurred in 13.k, two different computations on two different days:

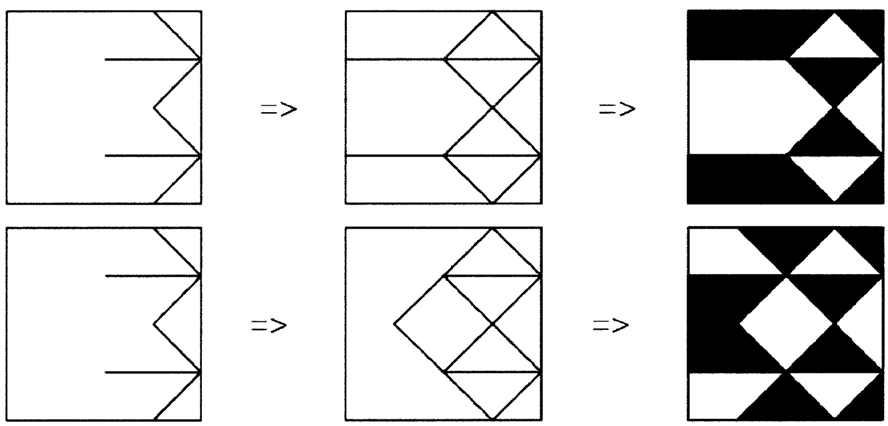
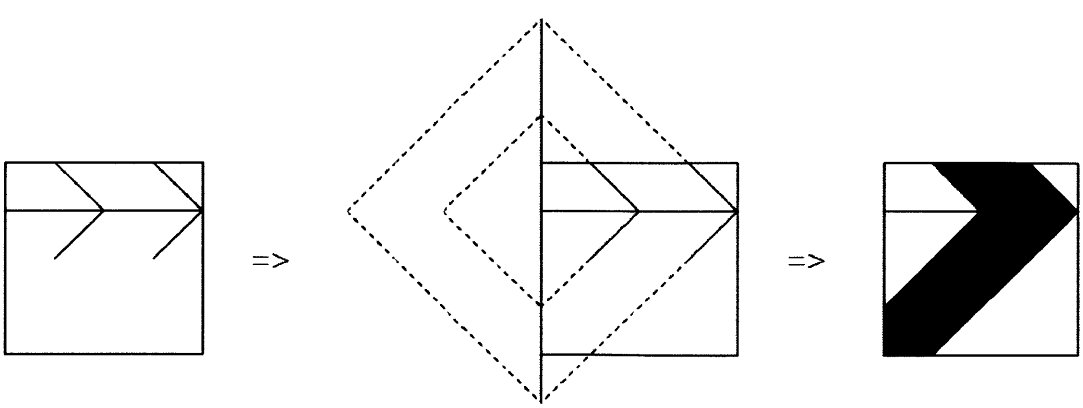


Figure 17. New designs based on 13.k. Two different computational processes and designs out of the same input, day#1 and day#2 respectively. Our seeing and embedding is dynamic over time.

Another example of this dynamism came up in 13.f: I had earlier produced a visual rule and schema that treated the two arrows as the corners of two large squares, along with the note "two hierarchical squares." Another day, I was seeing a group of triangles instead:



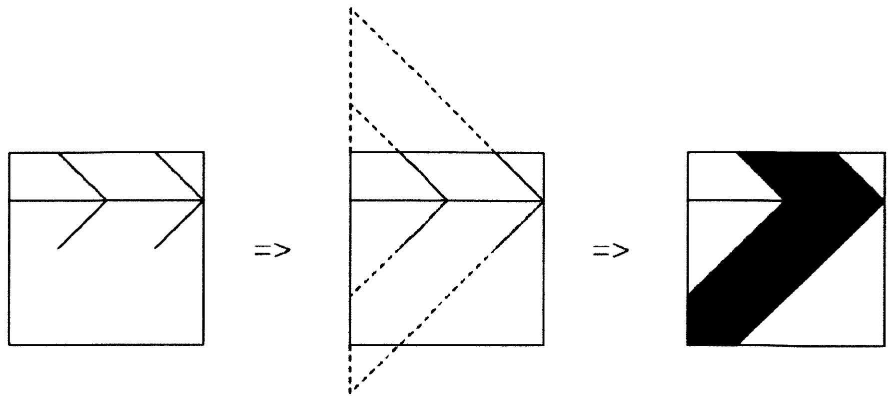
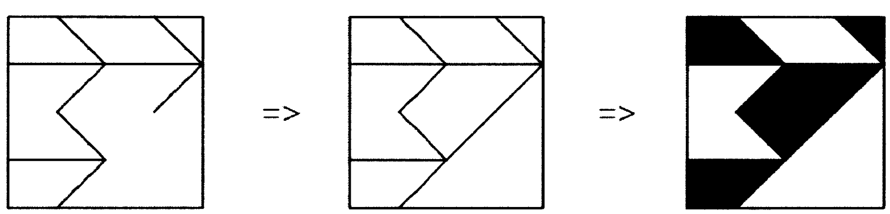
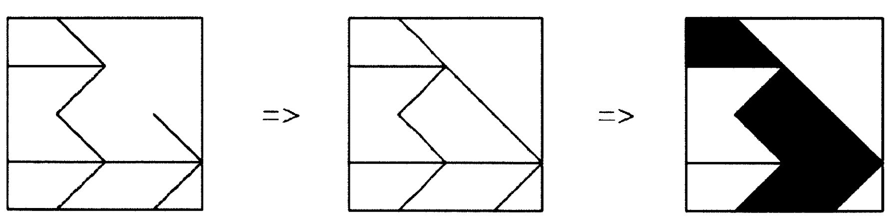


Figure 18. New designs based on 13.f. Two different computational processes out of the same input, same design, day#1 and day#2 respectively. Our seeing and embedding is dynamic over time, even though final designs may look the same.

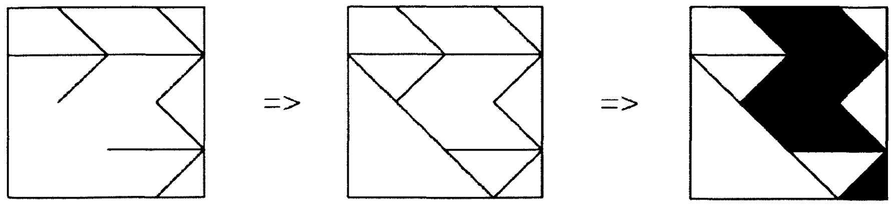
Even though the initial stimuli were the same (13.f), and the visual designs as the end product look the same, my computational processes were different because I *saw* differently. Using the same visual input and the visual schema $x \rightarrow prt^{-1}(x)$, I ended up performing different operations based on different ways of seeing. Keeping a continuous record of seeing by schemas like $x \rightarrow x$ along with visual rules or visual design computations is an invaluable education tool. Inspiration does not appear out of thin air; rather, it emerges through these deep sensory perceptual and aesthetic engagements. Maintaining a running record of these experiences in the form of design computations will bring forth inspiration, creativity and ingenuity. Some other designs that I produced out of the 2x2 population included the following:



(a)



(b)



(c)

Figure 19. 19.a – 19.c: New designs based on 13.l, 13.m and 13.n.

As we can see, simple designs generated on the 2x2 grid inspired me to see various different new designs. Interestingly, the new designs also look somewhat similar; this is the step that leads to the discovery of "style." Design students find such explorations highly useful and encouraging in developing their idiosyncratic visual languages, grammars and styles. Furthermore, what is pedagogically even more important is that these explorations encourage talk about characteristic perceptual heuristics that students utilize while seeing these new designs. In the above series of examples, how did I see the new designs? What did the design process look like? What schemas did I use while I was seeing and doing? Such questions bring forth externalized conversations about our sensory-perceptual and aesthetic-experiential thinking. Cultivating mindfulness, more fittingly cultivating *eyefulness* and *handfulness*, about our design processes and heuristics happens by to going deeper into such conversations on shape and form. They guide students in exploring where their aesthetics are taking them and how their aesthetic sense is developing step by step through an eyeful and a handful of designs.

3.5 Reflecting on Visual Reasoning with Visual Schemas

Reflecting on our seeing, exploring our visual reasoning and contemplating on our decisions are creative, productive design activities. For the initial new design I produced out of the 2x2 grid, I would like to reflect on my visual reasoning and slow it down. I am going to use my eyes, my hands and visual schemas to capture the process. In each step, I am going to contemplate these with the questions *"what am I seeing?"*, *"what am I drawing?"*, *"which schemas am I employing?"* I suspect that this experiment is going to make me make me recognize the quick moves and reasonings of my eye, observe the sources of my sudden inspirations and imaginations for new shapes and forms, and create the meaningful parts and wholes for my design process. My design computation had 9 steps, and I utilized a number of basic schemas as I went along.

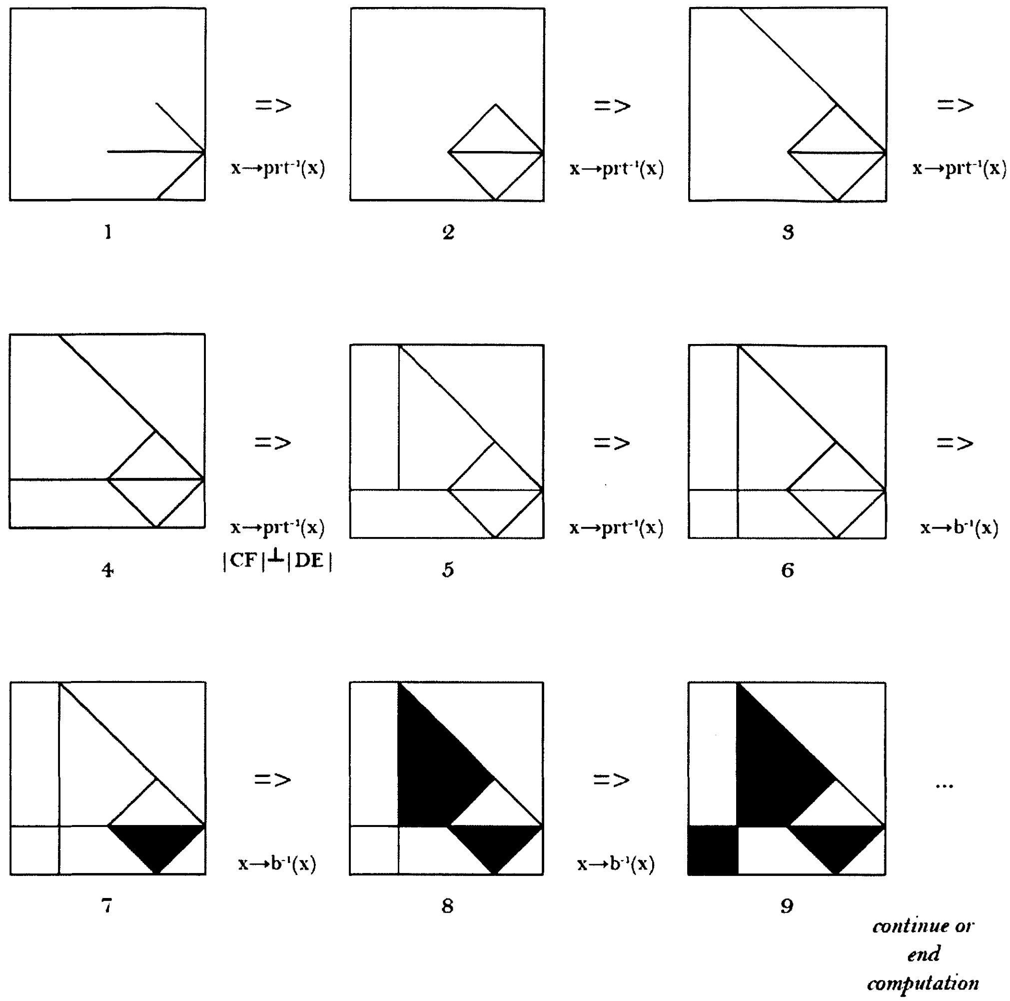
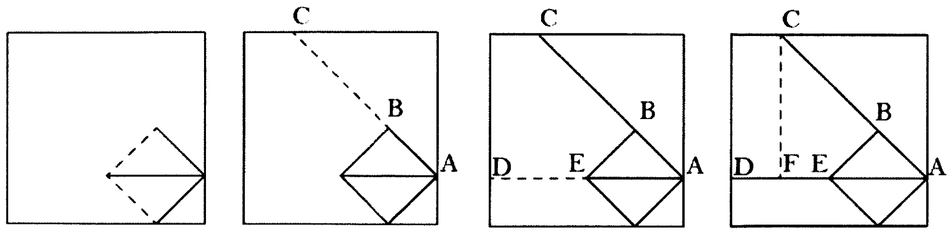


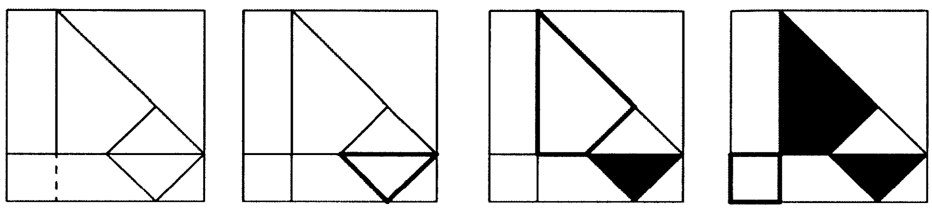
Figure 20. One of the visual design computations for design 14. This 9-step procedure captures free-flow and open-ended processes of exploration and discoveries. Visual schemas clarify our visual reasoning and help us to keep track of what we are seeing and doing.

During the course of this computation, I was exploring some of the visual ideas that appeared to me in that moment. For instance, going from step 1 to 2, I was interested in creating a square-like shape, as shown below in Figure 21.a. Similarly, I was interested in creating new lines and organizing the picture plane further, which I followed through in steps 3, 4, 5 and 6. I explored these possible traces, as iterated in Figure 21.b, 21.c, 21.d, 21.e. Then, I became interested in creating planes by taking the inverse boundaries of particular shapes that I saw, carried out in steps 7, 8 and 9. The shapes – boundaries, outlines – are highlighted below in 21.f, 21.g and 21.h.

When I reflect on my heuristics, first I was creating new lines and shapes in order to organize the picture plane and increase the potential for my seeing and doing in the next steps. In this episode, I repeatedly utilized the inverse part schema $x \rightarrow prt^{-1}(x)$ in order to explore new parts that I could introduce. Then, in the second episode, I recursively used the part schema $x \rightarrow prt(x)$, followed by the inverse boundary schema $x \rightarrow b^{-1}(x)$. I picked out particular outlines in order to create planes. I can also *retrospectively* call these episodes *sub-routines* of the complete visual computation. I can come back to these schematic heuristics and sub-routines in the future, as they have proved productive for my visual exploration.



(a, b, c, d)



(e, f, g, h)

Figure 21. 21.a – 21.h: Some visual reasoning steps that may present different possibilities. In 21.a – 21.f, I introduce new lines by repeatedly using the inverse part schema. In 21.g – 21.i, I highlight what my identity relations are. These identity relations then specify my planes after the application of inverse boundary schema.

As I look at my computation again, I see that I can make it more concise by going directly from step 6 to step 9, by an interesting identity relation $x \rightarrow x$ that catches my eye, which I show in step 6.1. By the different assignment in the identity schema, my seeing – hence my computational process – is different:

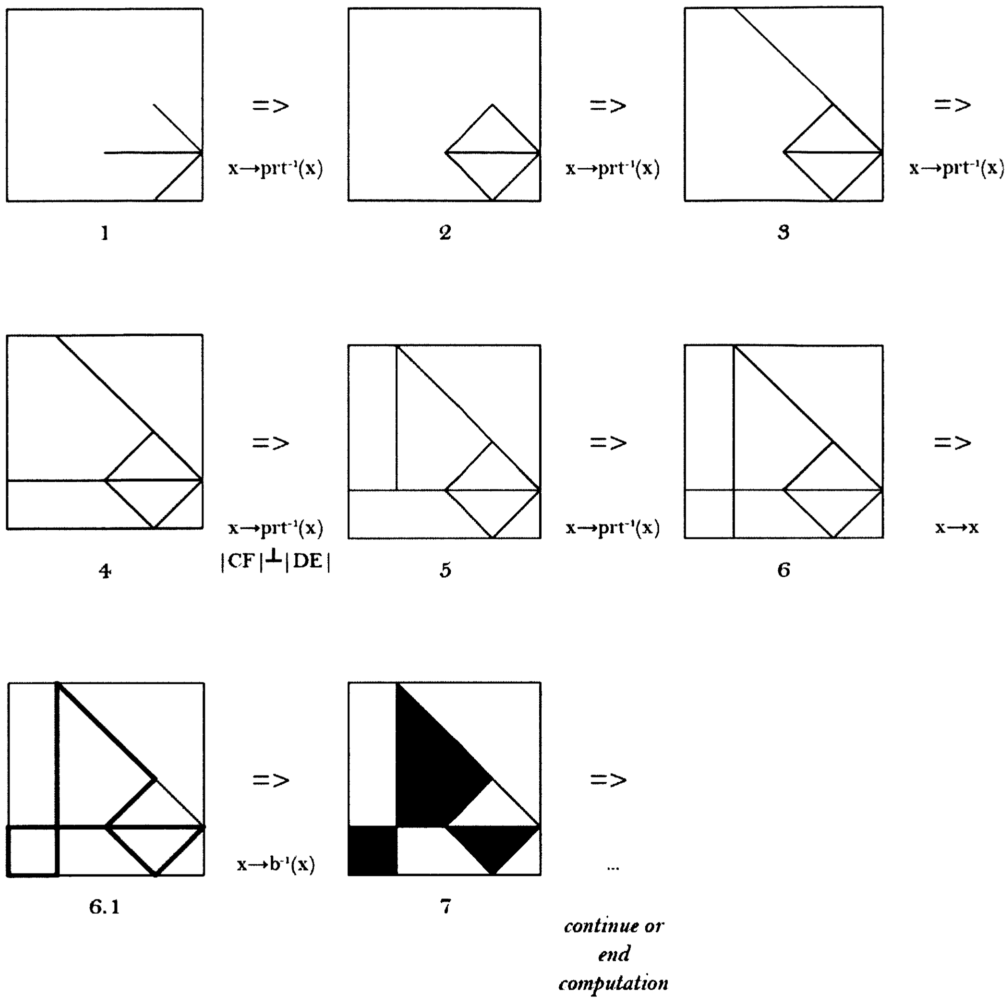


Figure 22. By different assignments in the identity schemas, my seeing – hence my computational process – can be altered.

One significant pedagogical moment in this exercise is also the lesson that nothing stays for too long as what it is. There are only momentary resolutions in the formalization of the whole into parts. To be able to move and shift between these various shapes creates aesthetic moments for me. In fact, as I was writing the sequence for my design computation with visual schemas, I come to the realization that I – my eye, my mind, my hand – actually do more than I previously thought or consciously recognized. The process I described above can also be expressed as a visual exploration; my sensation and perception can be slowed down; this is parallel to the notion of introducing layers or steps in the previous exercises. I can take note of the shapes as they unfold in time and capture them in layers (space) in different layers – therefore, create a spatio-temporal representation of my visual exploration, which would look like this:

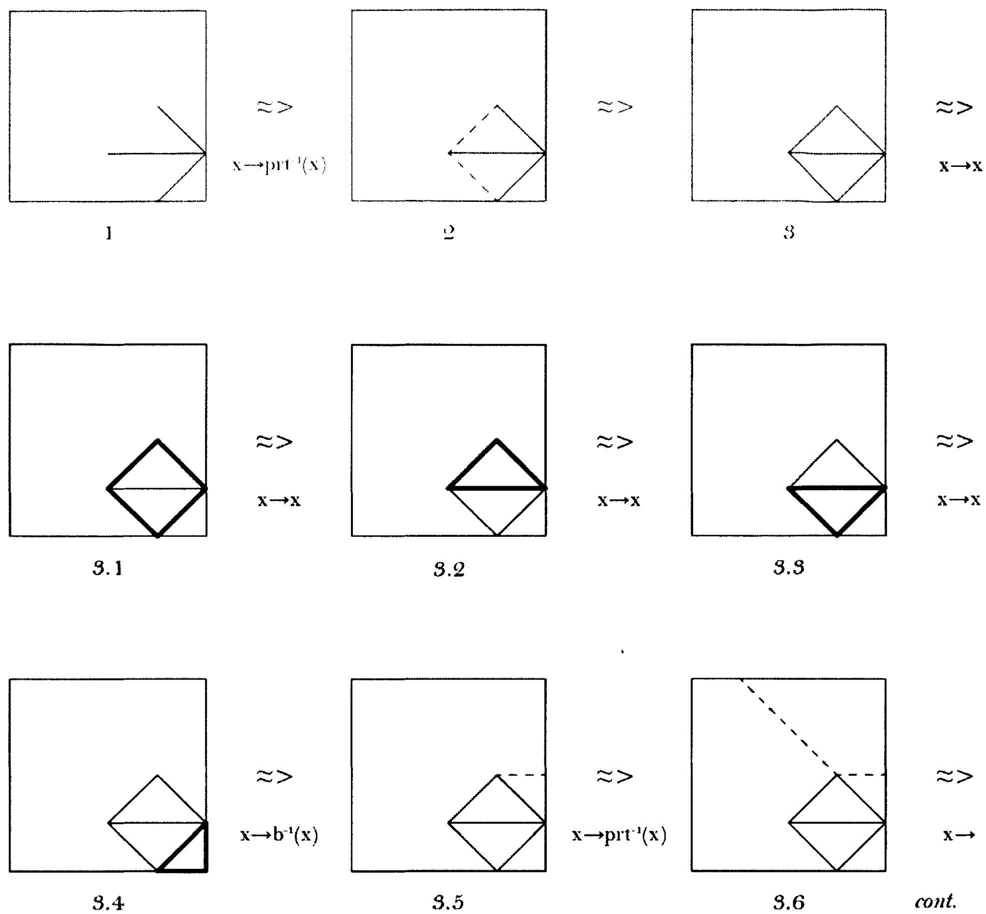


Figure 23. *Part 1 (of 6)* of my visual exploration for design 14 captures free-flow and open-ended processes of exploration and discoveries. We can explore our sub-routines by re-seeing our steps of derivation and practice in counting the parts of the whole.

In this exercise, I keep my initial visual computation and the step numbers the same. The second time that I see, my visual reasoning changes. As I begin to see more steps in between, I introduce them as new steps in between the initial steps. For instance, in Figure 23, my visual computation stayed the same in the first three steps. However, I soon realized that I was visually reasoning in-between step 3 and step 4. I captured these steps by adding tenth decimals. For example, the steps that I expanded between step 3 and step 4 took the names 3.1, 3.2, 3.3, and so on. In these relatively intermediary steps – relative to the initial visual computation - my eye was picking out shapes like a square standing on its edge (23.3.1), then two triangles respectively within this square (23.2.2 and 23.3.3), then a smaller triangle at the bottom-right corner (23.3.4). It was even seeing lines and shapes that were not there, especially by rapidly performing the visual schema $x \rightarrow prt(x)$ and $x \rightarrow prt^{-1}(x)$. In 23.3.5, I was checking for a line that extended from the top point of the square perpendicularly to the edge. In 23.3.6, in addition to that line, my eye was checking for an extension from the top-right edge of the square, extending in 45 degrees until it met the edge of the canvas.

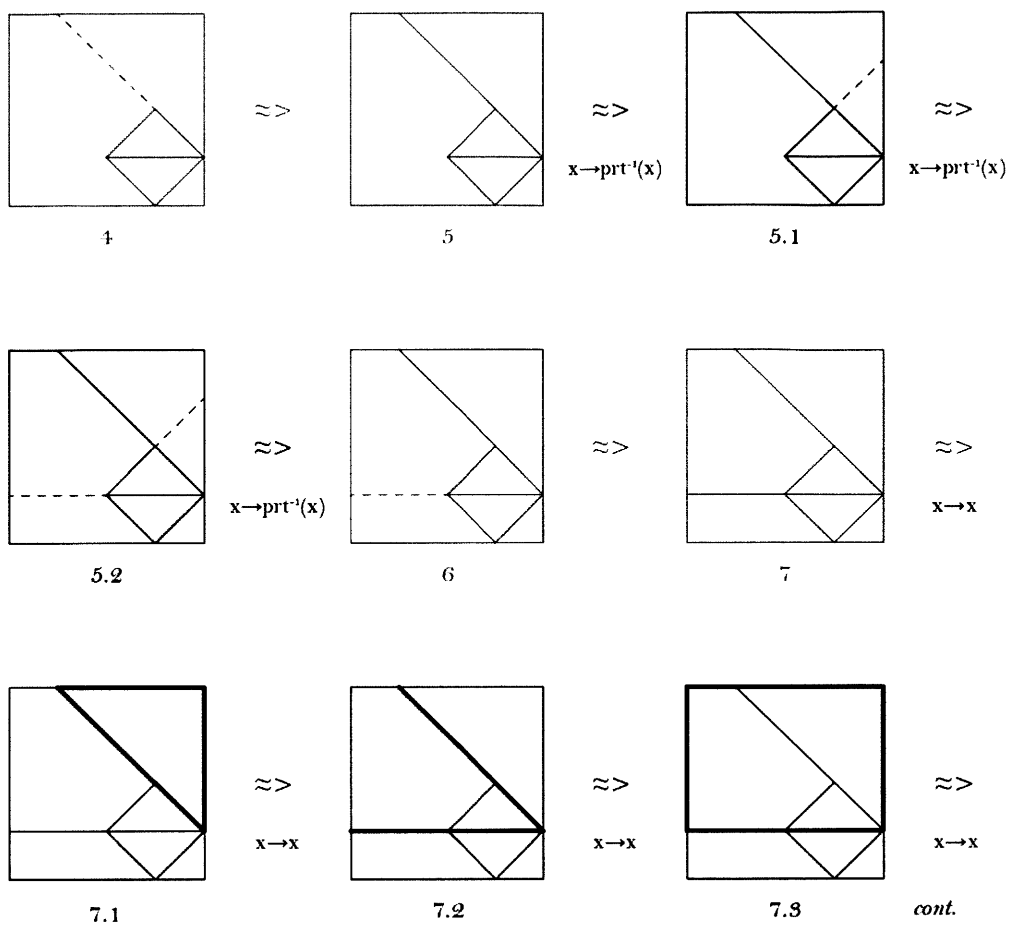


Figure 24. *Part 2 (of 6)* of my visual exploration for design 14 captures free-flow and open-ended processes of exploration and discoveries. We can explore our "sub-routines" by re-seeing our steps of derivation and practice in counting the parts of the whole.

As I thought I had captured my visual reasoning in between step 3 and step 4, I moved on to looking and seeing in the following steps. My visual computation stayed in the same route for step 4 and step 5, but I saw two more embeddings between step 5 and step 6. Again, my eye was checking for certain lines that extended from the edges of the square to the edges of the canvas. Alternatively conceptualized, my eye was connecting two points from a shape and a point on one line of the boundary. Or, if seen in a planar way, my eye was calculating the division of the pictorial plane (or the canvas) into shapes like triangles, squares, rectangles or quadrilaterals.

After moving on to step 6 and step 7, in-between step 7 and step 8, my embedding began to become rich and delightful. I captured twelve embeddings after I had produced step 7. Physically, perceptually and phenomenologically, the increase of entropy and ambiguity in step 7 resulted in the sudden increase of seeing and embedding potential – and with it, I argue, a sudden increase in sensory perception and aesthetic experience. A similar increase was captured in-between step 9 and step 10, as well as step 11 and step 12. I can confidently note here that the most fun and delight I obtained from this design exercise occurred in these steps, where I was seeing and drawing these various shapes within my designs.

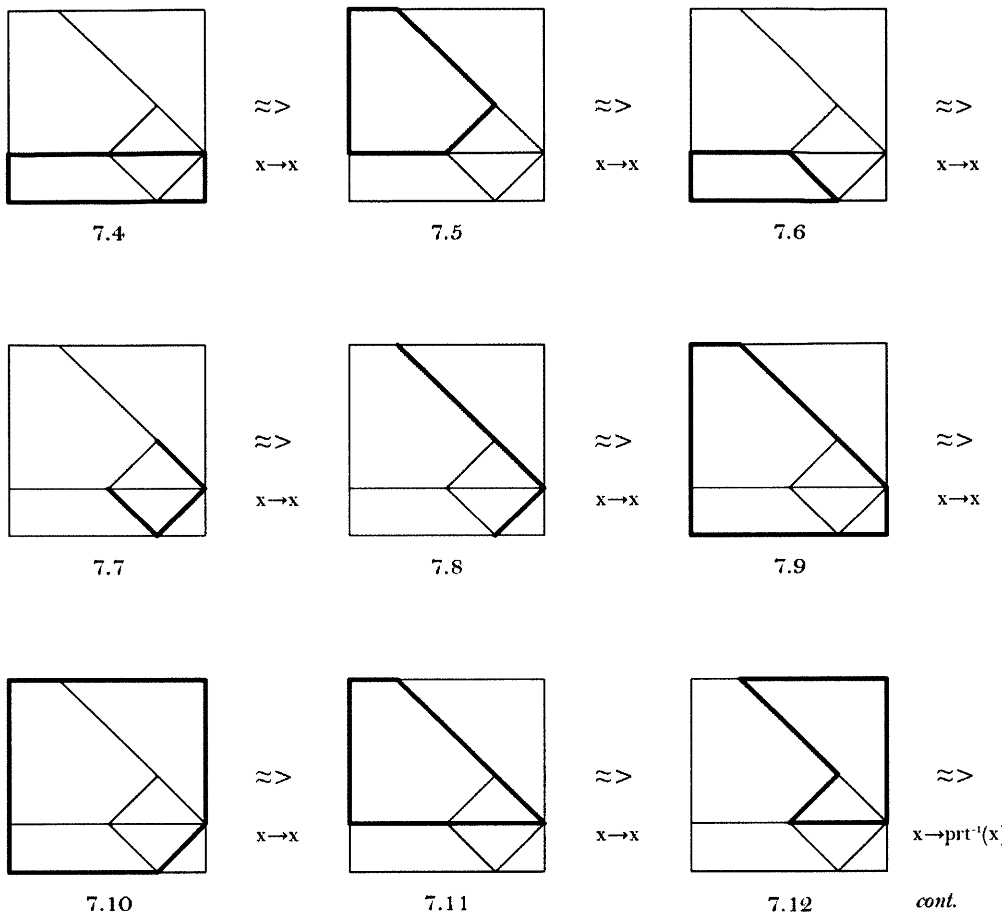


Figure 25. *Part 3 (of 6)* of my visual exploration for design 14 captures free-flow and open-ended processes of exploration and discoveries. We can explore our "sub-routines" by re-seeing our steps of derivation and practice in counting the parts of the whole.

One insight that I developed in this exercise was that whenever I embed a shape in the whole, my eye seems to check for the emergence of other shapes that appear simultaneously. This leads to the acknowledgement of a personal design heuristic that aims to point to the possible creation of various shapes by the introduction of a minimal number of lines. For instance, my eye checks for potential lines that are in strategic locations; when or if I introduce them, they lead to the emergence of a number of shapes that share that particular line. Of course, efficiency is not the keyword here. My claim is not an aesthetic rule that states "the introduction of minimal number of shapes that result in the generation of maximum number of possible shapes is an aesthetic shape." Moreover, there would be a dilemma here, of assuming shapes as *objects* and not staying in the malleable visual realm wherein shapes are not objects but are merely visual stuff. This is not an aesthetic rule; it is simply a heuristic that I came to be conscious of. I also came to the conscious fact that my eye seems to be pleased whenever I am able to do this. It is like a small fun game. It is not a goal for design; it is not a universal rule of aesthetics. It is simply a personal heuristic that I employ.

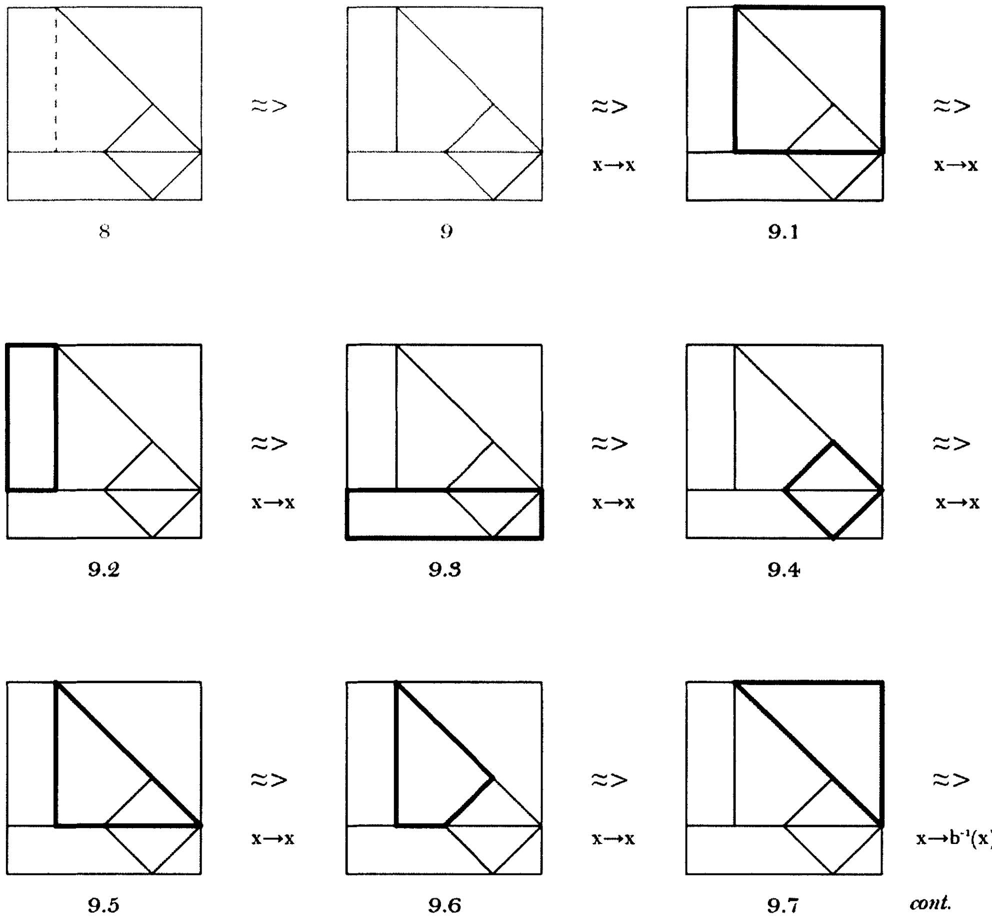


Figure 26. *Part 4 (of 6)* of my visual exploration for design 14 captures free-flow and open-ended processes of exploration and discoveries. We can explore our "sub-routines" by re-seeing our steps of derivation and practice in counting the parts of the whole.

Another insight that I developed through this exercise was the correlation between my visual reasoning and schematic reasoning. When I was seeing and drawing, the simultaneous activity of writing visual schemas made me go deeper into my aesthetic experience. In addition, the schematic description of my design or design step became the intellectual component of my aesthetic experience. When the intellectual experience coupled with my purely sensory perceptual experience, my aesthetic experience increased exponentially – especially if I was able to find an appealing schema description that I thought exactly explained what my eye was doing.

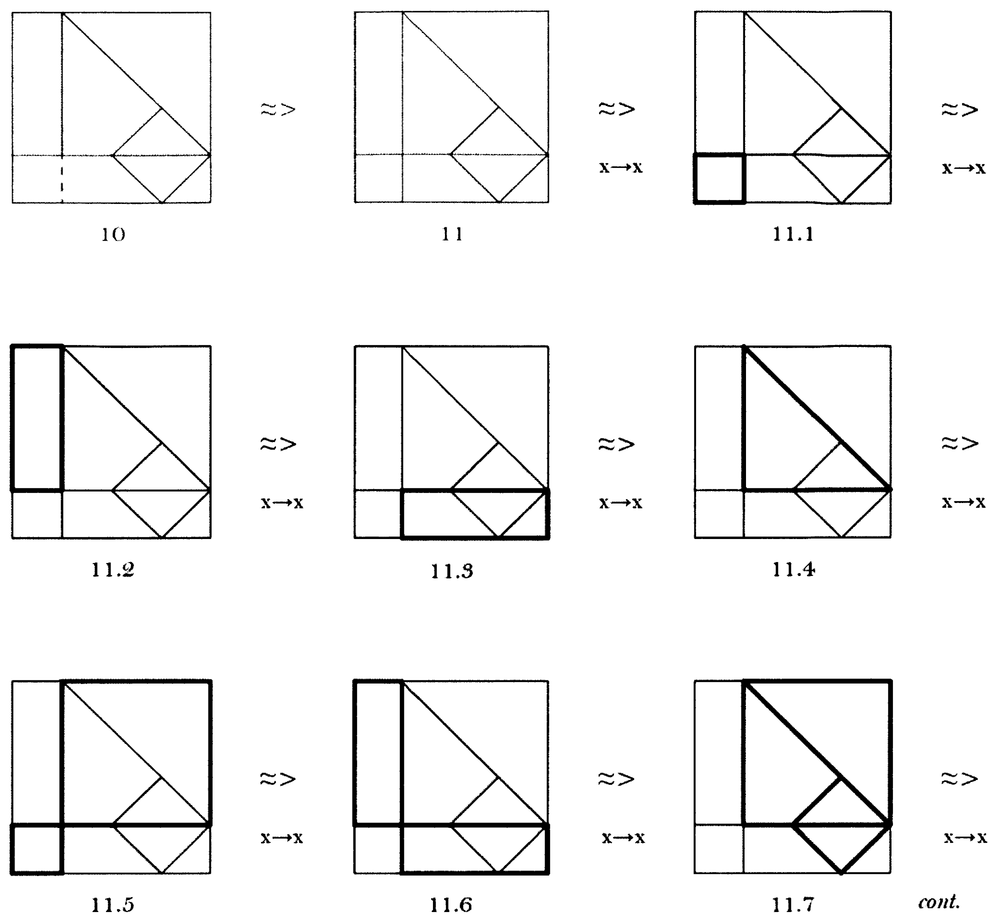


Figure 27. *Part 5 (of 6)* of my visual exploration for design 14 captures free-flow and open-ended processes of exploration and discoveries. We can explore our "sub-routines" by re-seeing our steps of derivation and practice in counting the parts of the whole.

In addition to discerning shapes, my eye also began to pick out certain identities, transformations and spatial relationships. The rectangles that I see in 27.11.2 and 27.11.3 can also be identified with the identity schema x → x, then the Euclidean transformation schema x → t(x). The rectangle in 27.11.3 can also be described as a 90-degree rotated instance of the rectangle in 27.11.2. Correspondingly, I was also counting the spatial relationships between certain shapes and their possible instances. In 27.11.5, I was discerning the possible spatial relationship between one square and another scaled square. In 27.11.6, I was discerning the spatial relationship of two rectangles. In 27.11.7, I was discriminating the possible spatial relationship between two squares, in addition to four triangles defined by the same shapes.

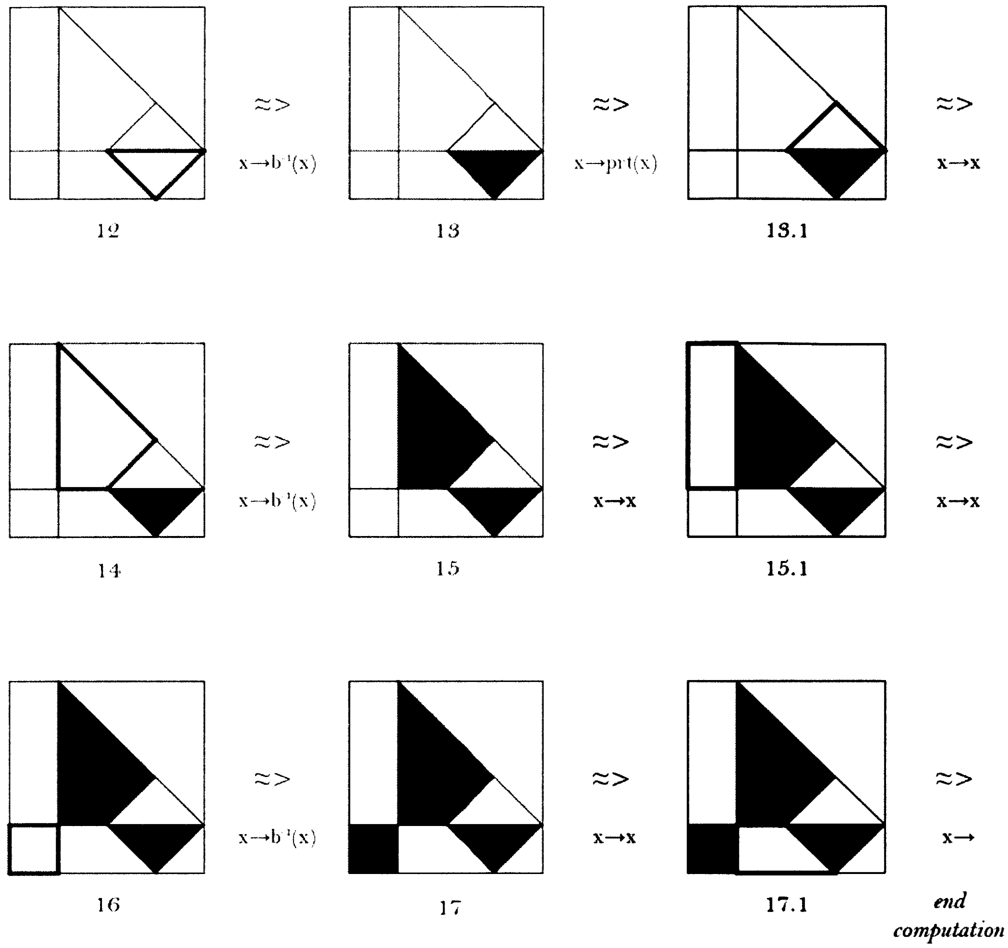
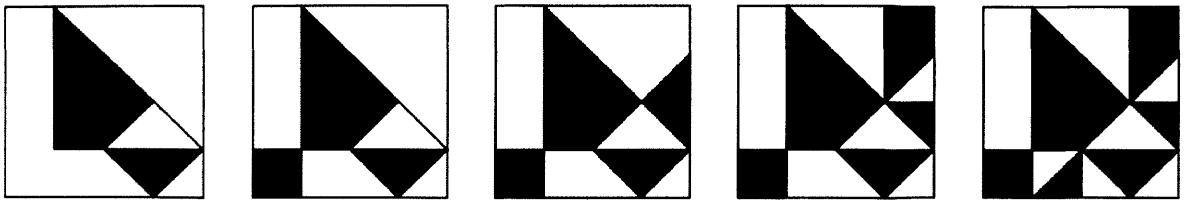


Figure 28. *Part 6 (of 6)* of my visual exploration for design 14 captures free-flow and open-ended processes of exploration and discoveries. We can explore our "sub-routines" by re-seeing our steps of derivation and practice in counting the parts of the whole.

Finally, in the last chunk of the visual computation, I realized that I had already determined to work with particular shapes and discerning them by turning them into planes. While doing this, my eye was following a counter-clockwise route, checking the black planes and also confirming the white planes. Visual computation stopped after step 17.1, as I completed the visual motion. I also acquired the insight at this stage that the ambiguity *seemingly* decreased with the introduction and definition of planes after step 12. With the reduction of shape ambiguity, my sensory perceptual movements decreased and so did my aesthetic pleasure. However, the next day I discovered how I could make this process indeed very, very amusing again: If I start to embed planes within the planes already defined, black or white, I would have various new potential shapes to explore, increasing the sensory-perceptual and aesthetic experience. The lines and planes that I can embed are infinite!

Certainly, the more I look at these visual sequences, the more I see and embed each time, hence increasing the sensory perceptual and aesthetic experiential potential. In fact, there are infinitely many layers and steps that I can study out of this simple visual computation. Noting the initial design that I generated in the initial visual computation, the slowed down visual computation provided me with alternative ideas about design as seen below, by pointing at different points, lines, planes; different identities, spatial relationships, transformations and boundaries; and different visual sequences described by different visual schemas.

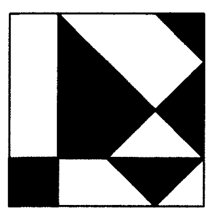


(a, b, c, d, e)

Figure 29. 29.a – 29.e: Different designs can be generated based off of the slowed down computation process.

Our visual explorations – as shown in Figure 23 to Figure 28 – in their entirety may contain seemingly repetitive and redundant steps. However, I believe that the spatio-temporal representation of the slowed down visual exploration is still valuable and can serve the pedagogical purpose for students to realize, understand and finally embrace uncertainty and ambiguity; this can be a tool in the process of making friends and allies of them.

On the other hand, we can and should clean these steps up in order to clarify our visual reasonings. In fact, replacing these fuzzy steps with the precise steps of computation can also serve the pedagogical and pragmatist goal of "making our ideas clear."[108] One of the precise computational processes is the initial visual computation shown earlier in Figure 20. As discussed, the process actually involved seeing infinite possibilities of shapes while we are seeing, applying rules and applying schemas. Therefore, infinite visual computations can be generated out of one shape. Each alternative shape we see can take the computation in new directions. Among these for one possible visual design:



The visual computation would be as follows:

[108] Peirce, Charles S. "How to Make Our Ideas Clear." *Popular Science Monthly* 12 (January 1878), 286-302.

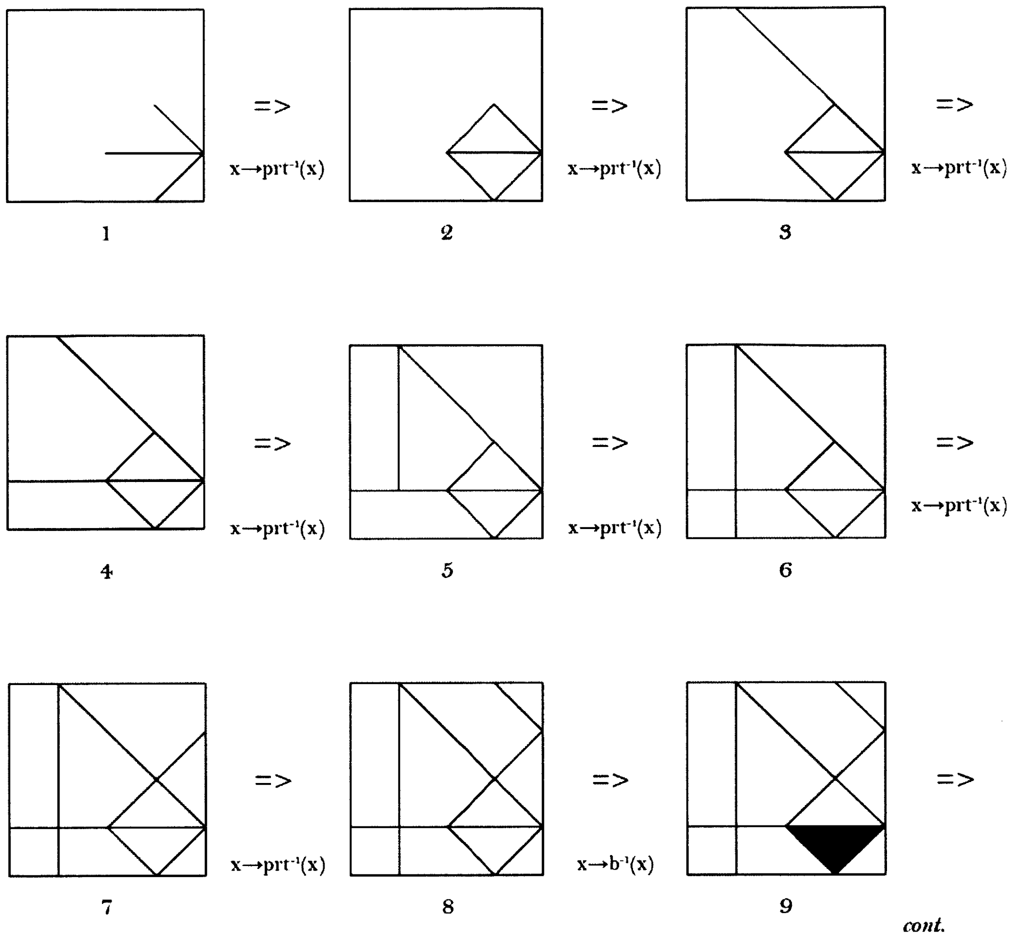


Figure 30. *Part 1 (of 2)* of another possible visual computation. This new process was inspired by extending the creative act of visual exploration.

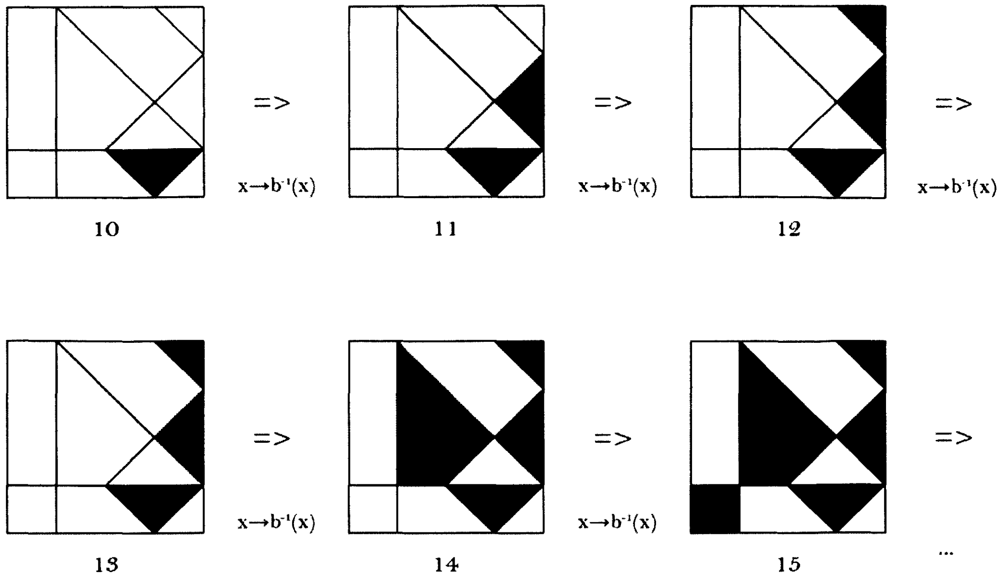


Figure 31. *Part 2 (of 2)* of another possible visual computation. This new process was inspired by extending the creative act of visual exploration.

3.6 □ + □ = ○, or How We Circle Those Squares: Learning to Reflect on the Eye

Stiny has echoed the maxim that is identified with Gestalt psychology -- "the whole is more than the sum of its parts," (or alternatively "the whole is different than the sum of its parts,") -- and has over the years provided *countless* cases where "seeing" as "gestalt insight" is more generous than "counting" predetermined "building blocks." In a simple grid structure he generated, he sought *to see* as opposed *to count*, in other words, analyze the *parts* as opposed to the *atoms*. He demonstrated his point with a regular grid structure constructed by triangles as its atoms:

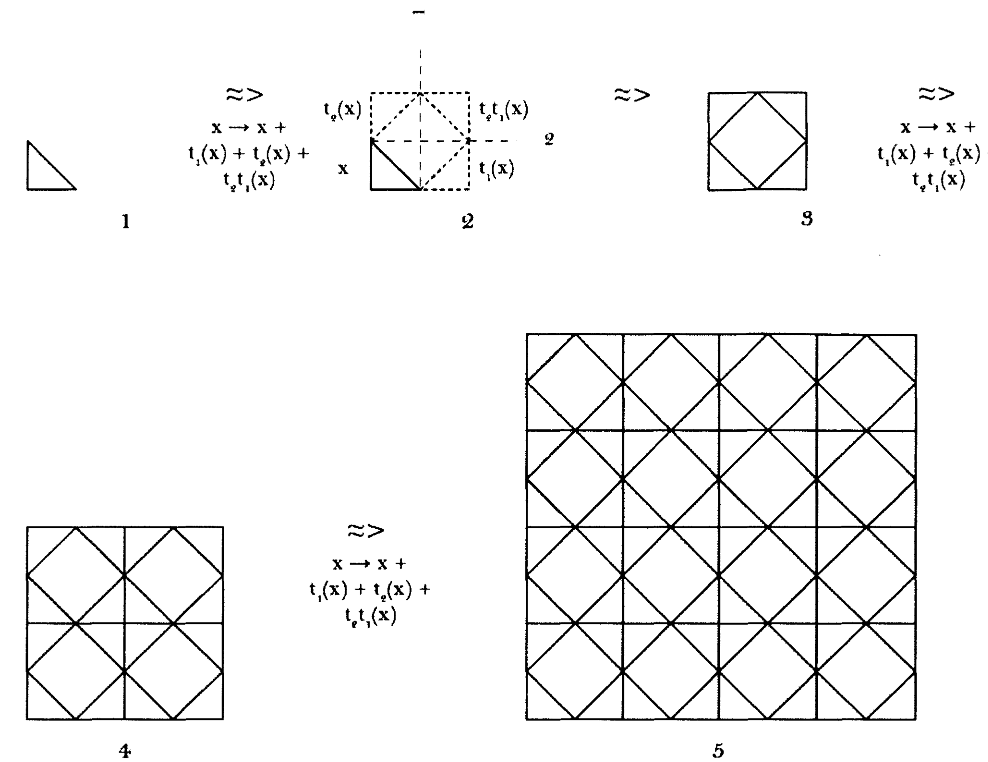


Figure 32. The grid example is taken from Stiny (2011).

When Stiny directed the question with reference to this example *"how many triangles do you see?"*, we come face to face with the discrepancy of counting with building blocks versus seeing. If we count the building blocks, we see that in the final design there are 64 blocks. On the other hand, if we see and count each and every triangle possible – still keeping in the "seeing triangles out of lines" mindset, – then there are 212 triangles. Stiny summarizes: "64<<212". Seeing is always more generous than atomic components. Furthermore, we can always see other things that we would like to see other than triangles – lines, squares, polygons, and many more. We can even see things that are not physically there, but our eye seems to catch them, as also discussed in the previous exercise.

Indeed, it was raised in one of the Proseminar in Design and Computation salons at MIT that some participants actually could see circles when they looked at the final grid pattern. Could we explain what might be going on here? Visual schemas provide a way to explain such a delightful visual procedure. Visual schemas are also generous in that they can always explain *how* we might be seeing, in this case the ephemeral circles. Our eye is probably catching a number of dots organized like an octagonal or circular outline and forming circles with $x \rightarrow b^{-1}(x)$:

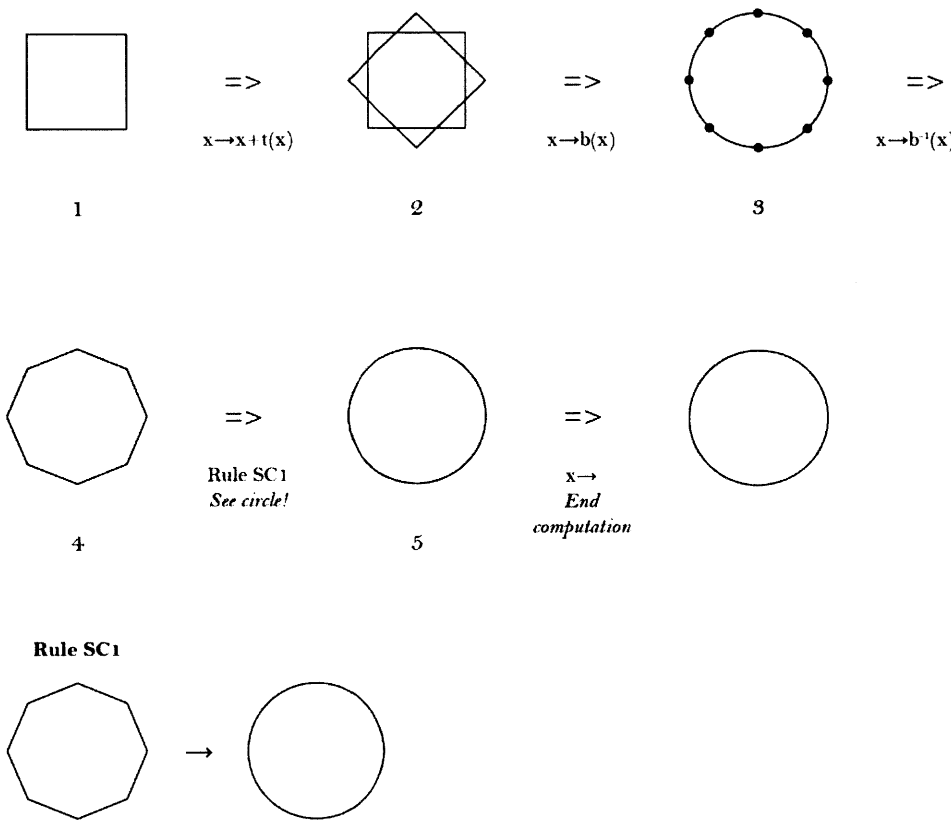


Figure 33. □ + □ = ○, following the eye and explaining it with visual schemas. Possible *visual sequence 1* for seeing circles out of squares. This computation was generated in the Proseminar in Design and Computation salon by the author, 2014.

Another possibility is that our eye might be seeing the intersection points of the two squares and again connecting the dots organized with an octagonal or circular outline to form circles with x → b^{-1} (x), as follows:

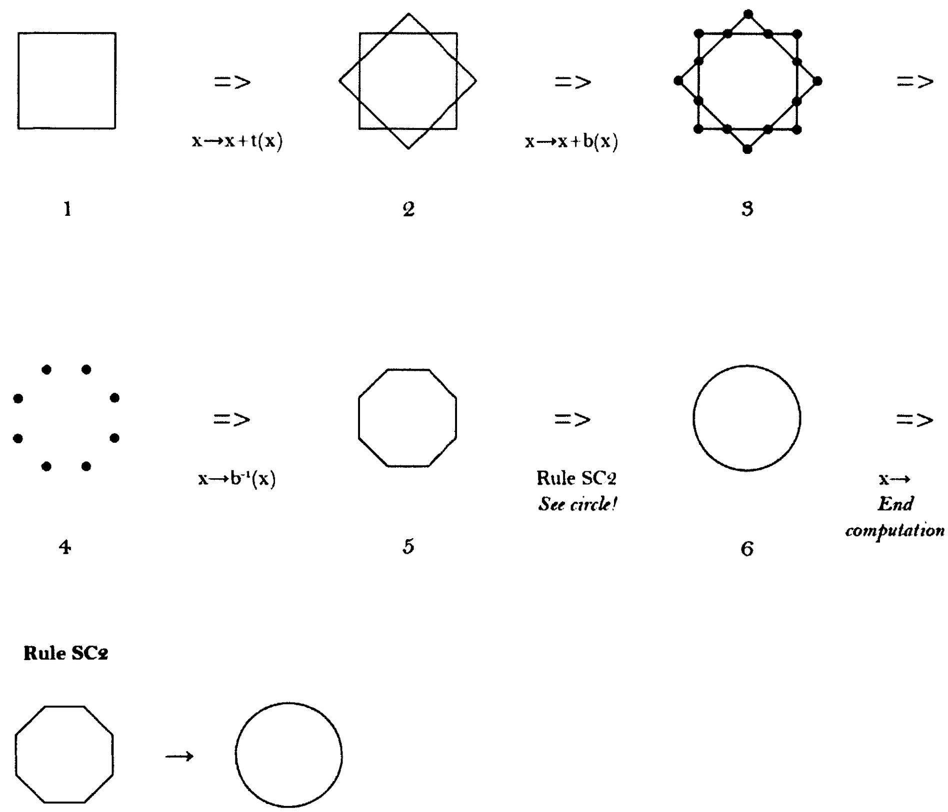
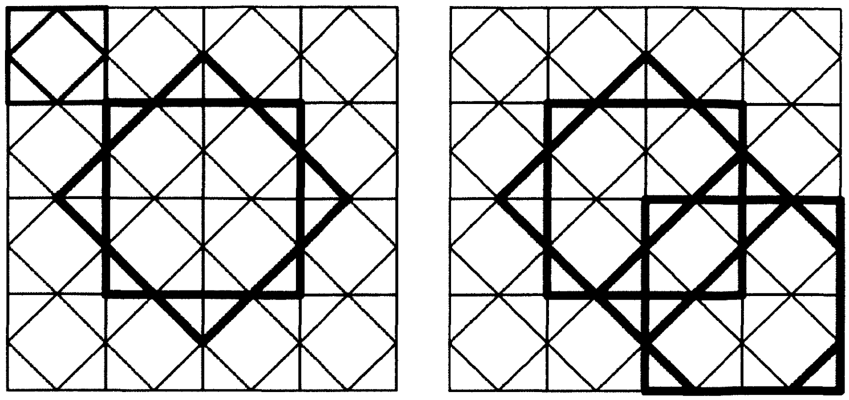


Figure 34. □ + □ = ○, following the eye and explaining it with visual schemas. Possible *visual sequence 2* for seeing circles out of square. This computation was generated in the Proseminar in Design and Computation salon by the author, 2014.

This is so delightful! Trying to describe my experience in terms of visual schemas adds to the aesthetics. In fact, sharing the sensory perceptual and schematic description with others (which took place at the Proseminar in Design and Computation, for instance) further adds to my aesthetic experience. As observed, as part of the sensory perceptual and aesthetic education in design education, learning to see and learning to count are among the skills that design students need to develop. In this example, my eye might have already seen the $x \rightarrow x + t(x)$ with the Gestalt insight. However, design computation with visual schemas concretized this experience and made it tangible and transferrable. After I followed my eye and kept asking what I was seeing, in addition to how many instances of the thing I was seeing, I discovered a number of visual computational processes for my little calculation □ + □ = ○.

Furthermore, this small algorithm encouraged me to reevaluate the initial input, look at the grid again, and led to the discovery that the □ + □ already exists in there, many times! Maybe my eye was already following those lines and connecting the dots, before I *[consciously]* even knew it. My visual reasoning had reasoned about it.



How generous is seeing? Shape grammars have been gauging the generosity of seeing by always inquiring with the two simple questions, *"what do you see?"* and *"how many do you see of it?"* Seeing is *infinitely* generous. By capturing the results of seeing and embedding with visual rules and visual schemas, we exercise design. We discern our momentary objects and make them corporal and verbally expressible in terms of operators and operations. Design students can put these moments to good use as the basis for further designs and creations. Instructors can also be watchful for these moments, which can be employed to guide students in their visual reasoning, feed students' with the right kind of exercises, and evaluate their skills in sagacity and abstraction.

In the following section, I continue to elaborate on important sensory perceptual and aesthetic experiential events like discerning part-whole relationships based on continual embedding. I provide an extension of the 2x2 grid exercise and the visual schema application $x \rightarrow \Sigma\, t^*(x)$. I give examples from visual elaborations on bigger grids – specifically 4x4 – and representative student works. I expand on how students' decisions are dynamically re-defined based on seeing and doing in a larger grid as shapes generate more intricate connections, visual relationships become more complex, visual material – hence aesthetic experience – become richer. I also touch upon heuristics to adjust the level of complexity in design, through simplifying it with visual schemas like $x \rightarrow x + t(x)$ to increase symmetries as needed, or through developing more complexity by disorder with diverse sums structured with the visual schema $x \rightarrow \Sigma\, t^*(x)$.

3.7 Generating New Designs: Exploring Schemas Further

In the previous sections, I observed and discussed creative design activities and visual practices in the studio setting by using visual rules and visual schemas. In this chapter, I explore some of the ways how we can continue with the visual exercises by progressing on the visual schemas $x \rightarrow x$, $x \rightarrow t(x)$, $x \rightarrow x + t(x)$ and $x \rightarrow \Sigma\, t(x)$. In the previous visual design exercise, we discussed some of the visual and reflective practices on the regular four square grid examples. We can build on the $x \rightarrow \Sigma\, t(x)$ visual schema exercise and create more complexity by simply enlarging the grid. We can, for instance, increase the number of the side squares from 2 to 3, from 3 to 4, and so on.

As we previously discussed in the 2x2 grid, we can also have different populations for the sum, whereby some of the cells do not receive the transformations of our unit. We discussed that for our 2x2 grid, if we wished to be exhaustive in exploring the entire design space, the number of cells being n, we had n=2x2=4 cells. The total number of designs are $2^n=2^4=16$. We were also able to draw each of these

16 kinds of populations and 16 designs easily. When we begin to explore bigger sums, where x goes to the sum of t(x), we quickly come to realize that the design space gets very big. The exponential difficulty of exploring the entire design space quickly emerges if we calculate the total number of possible designs as our sample grids get larger. In our 3x3 grid example (illustrated in the previous section), for n=3x3=9, and disregarding symmetrical isometries, we have $2^n=2^9=512$ possible designs; in our 4x4 grid, for n=4x4=16, we have $2^n=2^{16}=65536$ possible designs; in our 3x5 grid, for n=3x5=15, we have $2^n=2^{15}=32768$ possible designs.

More specifically, some of the possible populations in my 4x4 grid can be those with zero-units (1 design), one-unit (16 designs), two-units (120 designs), three units (560 designs), four units (1820 designs), five units (4368 designs), six units (8008 designs), seven units (11440 designs), eight units (12870 designs), nine units (11440 designs), ten units (8008 designs), eleven units (4368 designs), twelve units (1820 designs), thirteen units (560 designs), fourteen units (120 designs), fifteen units (16 designs), sixteen units (1 design). Note that the number of designs constitutes a mathematical sequence and different grids with varying cell numbers can be investigated in a correlated way, with possible guidance from Pascal's triangle and the Fibonacci sequence.

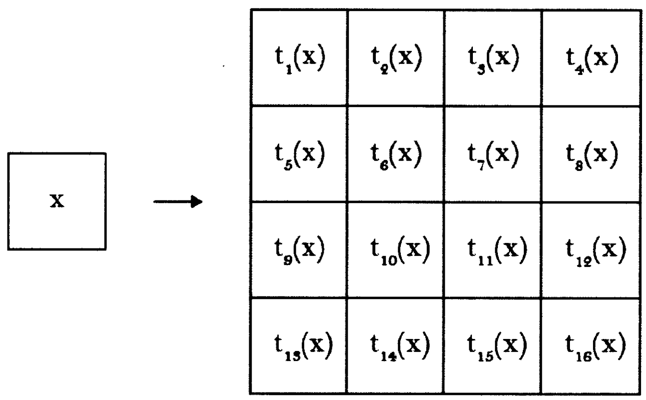


Figure 35. There are 65536 possible designs for a grid of 16 cells. Besides, this is only one step of the visual computation and in fact there are shape ambiguities. There are not only 16 squares but many.

While exploring design spaces is definitely a useful design exercise in helping students to increase mindfulness studies of form and our step-by-step reasoning, it has its shortcomings. While our creative output can benefit from being able to explore various "commensurate" – appropriate, fitting – options, our creativity can also develop by being exposed to high numbers of related visual designs that perpetually feed our sensory-perception, imagination and learning. In a group of associated designs, similarities, differences, proportions, comparisons can improve our power of discernment. However, generating the finite list of entire designs begins to become counterintuitive for my pedagogical goals, especially as the number of possible designs increase. Besides, this is only *one step* of the creative design process. The nature of my exploration – hence my design space – can and will change in the subsequent steps in an open-ended way as shown. Additionally, this computation, the 65536 options assume that there are only 16 squares in this grid. Indeed, due to shape ambiguity, there are many more!

In our creative design processes, we intelligently navigate design spaces in the moment as such, *in-situ* and in transient, fluid and fluent ways. While exhaustive design space exploration can serve as a useful design exercise, it designed to develop sensory-perceptual awareness. It is not a prescriptive design method, but rather a stimulant that provokes exploration of possible paths, so that we can experience trials-and-errors and come to decisions based on our momentary practical interests.

4 Learning with Shape Grammars in Basic Creative Visual Design Education

Practicing seeing and visual reasoning can be guided first and foremost by learning the notion and practices of embedding as described by shape grammars. A painting, a drawing, or a design is presented to us in the form a *whole*. When we see this whole, we begin to visually and spatially respond, to discern a number of parts, and to explore different relationships of this whole. Understanding part-whole relationships in this sense in reading and making visual designs is one of the most basic competences one develops in learning creative design. Exercising seeing is indeed the first topic that one is introduced to and it remains integral to each and every exercise in design education.

4.1 Visual Practices for Seeing, Embedding and Discerning Dynamic Parts and Wholes

For this purpose, I planned a number of design exercises that aimed specifically at seeing and embedding, and used these in workshops and classes that I ran at the Massachusetts Institute of Technology, Singapore University of Technology and Design and Izmir Institute of Technology. For the initial exercise, I used a number of paintings to initiate the conversation on shapes – points, lines, planes, and solids – to encourage students to formulate what they see explicitly. These paintings were projected on the screen for a class activity. Students responded quickly to this exercise by pointing out shapes they saw, how the shapes related to each other, and how the shapes were organized on the pictorial plane. Students also identified the properties of shapes like color and texture, as well as emotions that are embodied by them or hypothetically embodied by the painter while painting. This exercise proved to be highly successful in making the elements of visual perception and reasoning in the form of shapes and parts of wholes become part of the studio conversation.

Figure 36. Two sample paintings are discussed and studied verbally in the studio. Students are encouraged to speak up about what they see in the compositions, especially in terms of their structural elements of shapes, colors and textures. The selected paintings were *Sunday Afternoon on the Island of La Grande Jatte*, by Georges-Pierre Seurat (1884) and *Dusk in Venice*, by Claude Monet, 1908-1912.

Figure 37. Students are prompted to explain and point at the shapes they respond to, embed or discern. Horizontal, vertical or diagonal lines can provide a straightforward access to shapes, structure and visual organization. Visual designs present endless opportunities for us to respond to any kind of form or shape – points, lines or planes.

Through this exercise, encouraging students to talk about their sensory-perceptions and aesthetic experiences re-introduced a sense of the validity of their experience in the context of design. Despite the initial silences and hesitations, the activity quickly turned into a dynamic exercise in which students found themselves excitedly talking about what they would have otherwise brushed off as trivial or insignificant. Even simple activities like this help students understand the importance and consequentiality of seeing and embedding. In visual schematic terms, these exercises also introduced implicit practices with identity schemas $x \rightarrow x$ and part relation schemas and its inverses $x \rightarrow prt(x)$ and $x \rightarrow prt^{-1}(x)$. Through practicing these kinds of schemas and operations, students became increasingly comfortable in working with shapes, parts of shapes, spatial relationships between shapes and spatial relationships with the pictorial space, or the canvas.

Despite this validation of idiosyncratic ways of seeing, a number of pre-conceived ideas come up repeatedly: first, that there is one way of seeing the painting or design *correctly*, or that there are particular ways that the painter intended us see and that we should "discover" or "uncover" those, and second, that there are universal pictorial laws that dictate that we must all see in one particular way, and that any analysis shows some singular objective truth. These moments present us an opportunity in which to highlight the plurality of perception: that there is no correct way of seeing, or that the painters also see their work as we see it, or that there are no universal laws but probably only individual heuristics or patterns in visual reasoning, or that any analyses performed by the instructor or the students will hold multiple truths, and that we are all engaged in pluralistic perception and pluralistic aesthetics.[109] Students soon become convinced of the truth of these statements as they all begin to see similar and very different parts; their eyes guide them again. And their confidence soars!

4.2 Seeings and Doings, They are Pluralistic and Pragmatic

Parts and wholes, - i.e., referred to in our discussion as shapes, designs, and compositions – are not static entities. Parts and wholes are defined again and again each time we look at them. To cultivate the ability to capture parts and wholes, and to become comfortable with the dynamics of visual reasoning, the follow-up exercise to the verbal practice introduces drawing. Following from verbally analyzing paintings, students are given a number of printed copies of the paintings. For this exercise, I chose three paintings: *Washington Crossing the Delaware*, by Emanuel Leutze (1851); *Mont Sainte-Victoire seen from Bellevue*, by Paul Cezanne (1895) and *Jacqueline with Flowers*, by Pablo Picasso (1954). Copies of these paintings were given to the students in printed form along with a set containing tracing paper sheets, pencils, erasers and (optional) rulers. Students were given the instruction "capture, draw and trace the design elements – like points, lines, planes and colors – that you see, that capture your eye, that you think are perceptually important, or perceptually and structurally significant for this design." To this instruction, students responded by tracing lines and capturing some points and planes that they wanted to highlight. They were free to use multiple sheets if they preferred.

Students were slightly more hesitant when it came to "drawing" as compared to talking about shapes. The exercise seemed overwhelming at first. However, after the initial couple of points and lines, students became quickly encouraged to draw what they saw. They were enthusiastic about observing their own sensory perceptual and aesthetic decisions. The more they practiced seeing, the more they

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[109] Schusterman, Richard. *Pragmatist Aesthetics: Living Beauty, Rethinking Art.* Lanham, Maryland: Rowman & Littlefield Publishers, Inc., 2000.

became interested in becoming more conscious and mindful of their visual "sagacity." The act of drawing itself, the capturing of shapes on paper, soon provided highly encouraging feedback. Students felt liberated to move on to other steps in design. This exercise in this sense acts as a catalyst that propels design process. Additionally, normally a rather difficult concept in design education, abstraction, is also introduced. An activity that is based on shapes, abstract and geometric elements automatically introduces abstraction as the basis of visual design. Again, students implicitly utilized identity schemas $x \to x$ and part relation schemas and its inverses $x \to prt(x)$ and $x \to prt^{-1}(x)$ in their visual reasoning. The responses given to the exercise in one of the class meetings are shared below. Although similar schemas are employed, variety can be observed in the captured shapes.

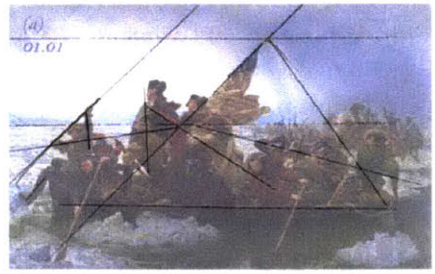
Figure 38. Exercises in seeing with the utilization of the schemas $x \to x$, $x \to prt(x)$ and $x \to prt'(x)$. Students responded to a number of paintings by visual analysis and reasoning. In the exercise, they were told to capture shapes they see on a new layer of tracing paper – in the form of points, lines or planes.

The first layer in this computation was the painting printed on a sheet of paper. The second layer was introduced in the form of a new sheet of tracing paper, placed on top of the first layer. Then, students captured certain shapes – traced them – on the tracing paper by employing the identity rule $x \to x$. This computation can also be expressed with an expanded rule $<x, 0> \to <x, x>$.[110] In this expanded rule expression, information on two layers is included. The first layer is utilized but kept as is, with the identity rule $x \to x$. The second layer – the new tracing paper layer – was introduced with the inverse erasing rule $0 \to x$. With this rule, we were able to remove the first layer that contains the painting. We were then left with the tracing paper as shown below. The rule application with layers is indeed significant because it utilizes the identity rule not in a passive but in an active way.

[110] For further details on how shape grammar formalism can work with layers, see: Stiny, George. *Pictorial and Formal Aspects of Shape and Shape Grammars.* Basel, Switzerland: Birkhäuser Verlag, 1975. On "n-tuples" and "n-ary relation among drawings," also see: Stiny, George. "What is a Design?" *Environment and Planning B* 17 (1990): 97 – 103.

=> ... =>

<x, 0>→<x, x>



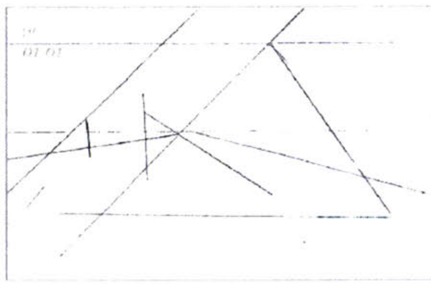
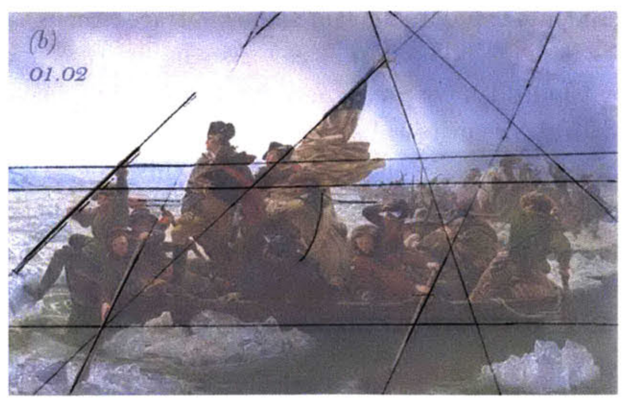
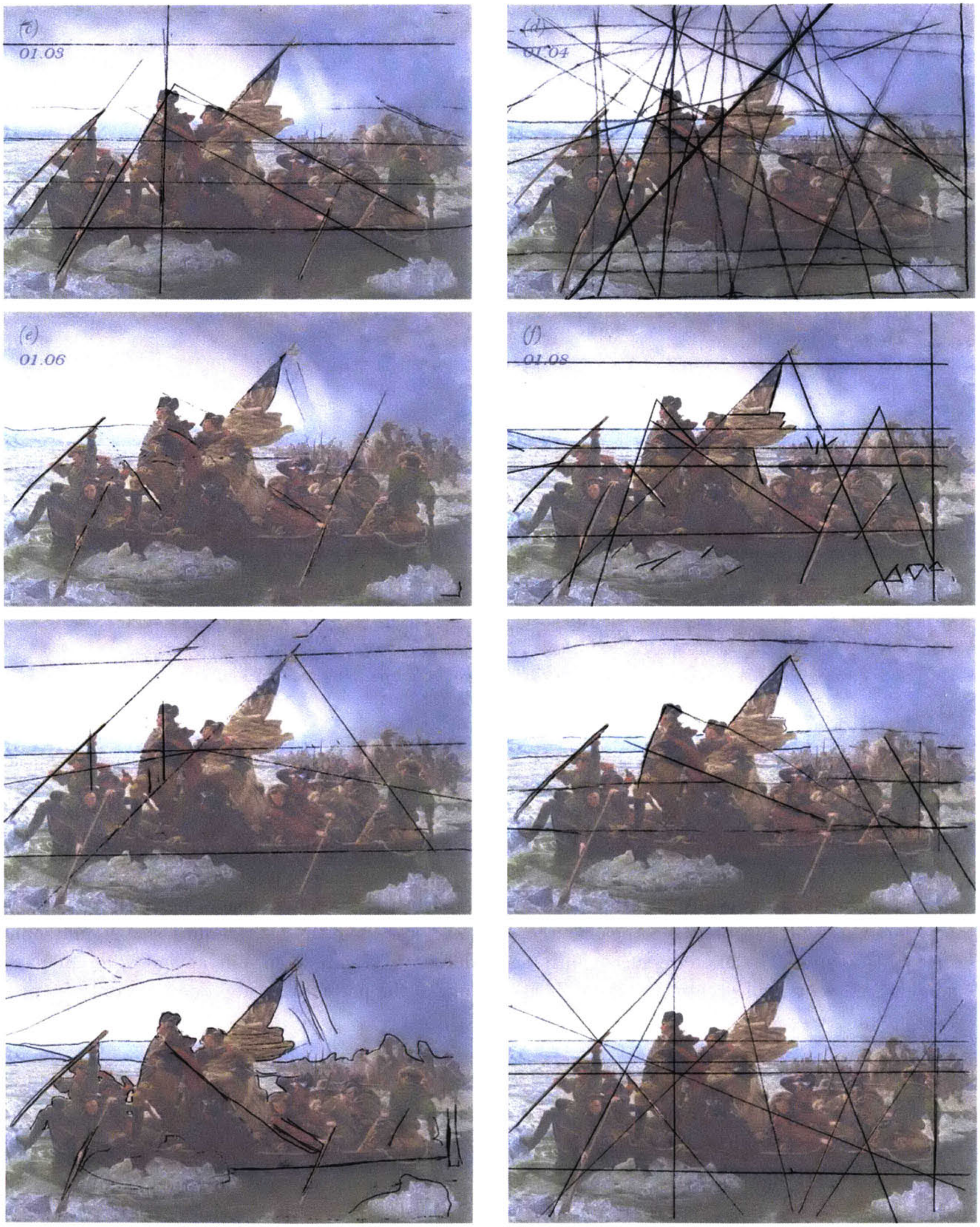


Figure 39. Students captured certain shapes – traced – on the tracing paper by employing the identity rule x → x. This computation can also be expressed as the expanded identity rule <x, 0> → <x, x>. As a result, a new layer is introduced.

This active form of identity rule application can be studied further by the continual introduction of new layers. Three layers can be expressed by the identity schema <x, 0, 0> → <x, x, x>, four layers by <x, 0, 0 , 0> → <x, x, x, x>, and so on. Another version of this exercise can be the instruction to students to draw directly on the painting sheet.




(c)
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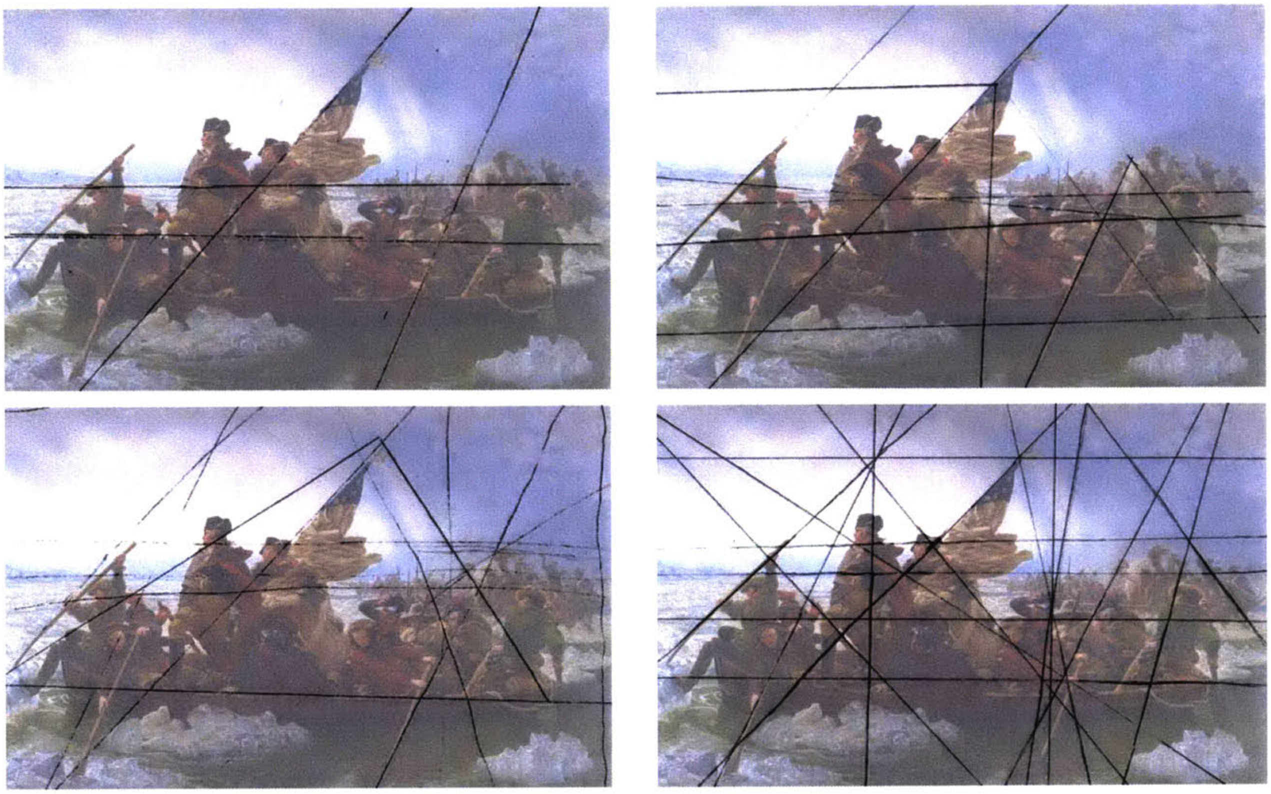


Figure 40. Images 40.a – 40.p are a group of responses from students in one workshop session. Novice designers traced over a printed copy of the painting *Washington Crossing the Delaware*, by Emanuel Leutze (1851). (Drawings are scaled. Originals are 9 inches by 12 inches.)

In design studio exercises, the pluralistic and pragmatic aspects of seeing are key notions that need to be repeatedly emphasized. Analyzing artworks or designs presents a good opportunity to highlight the plurality of ways of seeing and doing in a group of students and make them comfortable with their own visual processes. Seeing and doing are indeed *seeings* and *doings*. In fact, students were soon interested in comparing and contrasting their designs. This exercise – featuring Picasso's painting – facilitated talking, contributing to the class. In this particular session, students initiated the idea of taping drawings on top of each other on the window, observing the overlapping shapes and non-overlapping shapes. The exercise successfully engendered discussion about similar and different part-whole discernments and design processes. It also vitalized the point: next step does not only involve *either/or*, but also *and.*

Figure 41. In this particular session, students initiated the idea of taping drawings on top of each other on the window; observing the overlapping shapes and non-overlapping shapes. The exercise was highly successful in talking about the same and different assignments, part-whole discernments and design processes.

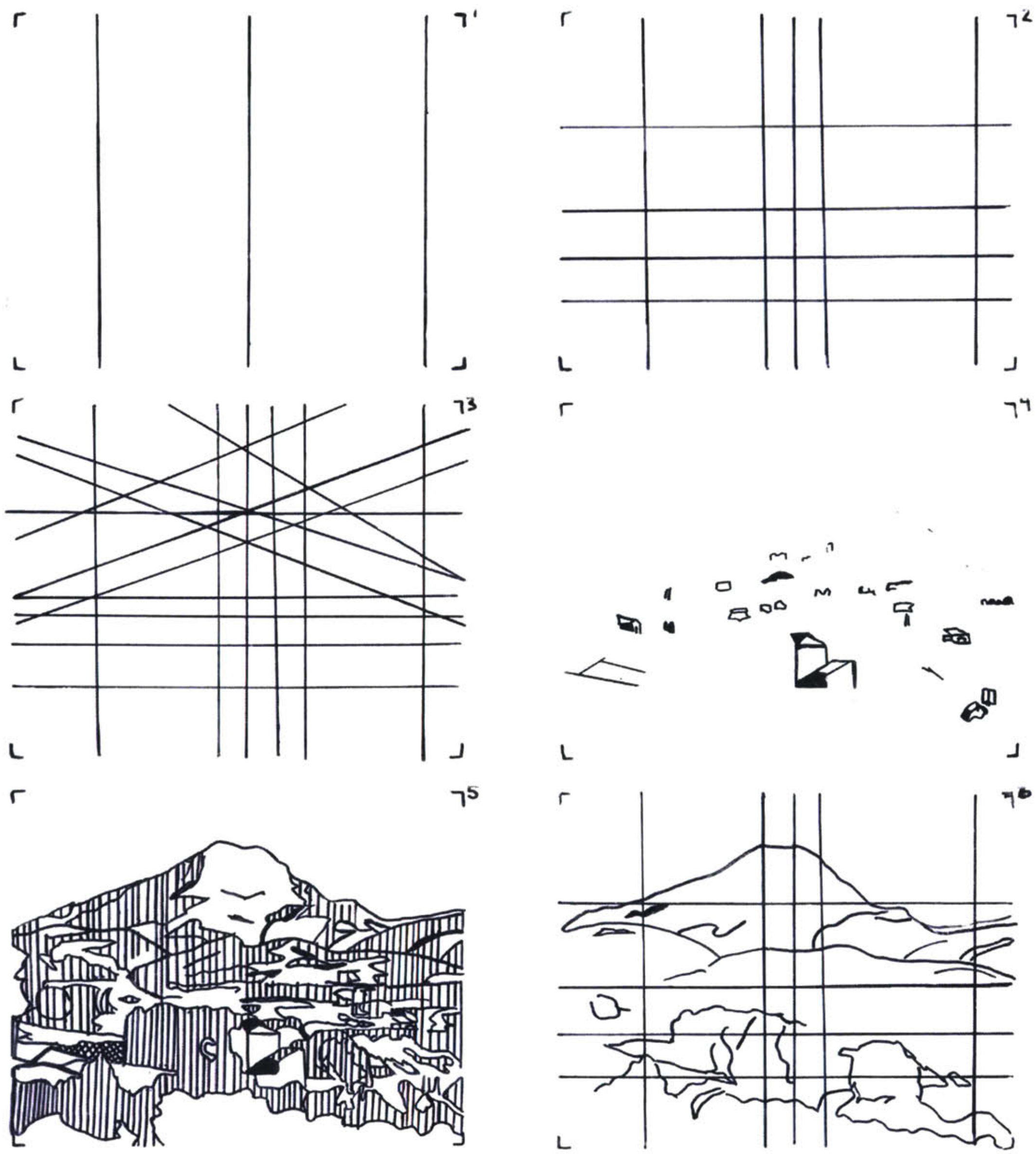
4.3 Seeing Fast and Seeing Slow, Slowing down Visual Reasoning by Layering

In analyzing or generating designs, seeing and doing can be enriched by enforcing a *slowing down* of visual perception, visual reasoning and aesthetic experience. Following the exercises in which analyses of various paintings are performed, I introduced another design exercise to slow down visual perception and reasoning. In this exercise, students were given a set of paintings to study in the same manner as the previous exercise, with the same tool set, by capturing the points, lines and planes that they see and determine as perceptually significant. They were given the same instruction "capture, draw and trace the design elements that you see, that capture your eye, that you think is perceptually important, or perceptually and structurally significant for this design."

This time, however, students were asked to draw a pre-determined number of different *layers*, in order to create different groups of visual information. At this stage, students were provided both tracing paper and transparency sheets. They could practice on tracing papers if they desired; but, a specific number of drawings were requested on transparency sheets. Students were allowed to use different layers of information as they continued to draw, to continue creating new layers. Students can also be given other semi-transparent or transparent materials to perform this exercise, such as polyester sheets or other creative materials.[111]

[111] Flemming also discussed on the idea of layers in a computational setting: Flemming, Ulrich. "Syntactic Structures in Architecture." (pp. 31 – 47.) In McCullough, M., Mitchell, W.J. and Purcell, P. (Ed.s.) *The Electronic Design Studio*. Cambridge, MA: The MIT Press, 1990. On layers and transparency, also see: Rowe, Colin, and Slutzky Robert. "Transparency: Literal and Phenomenal." *Perspecta* 8 (1963): 45-54. Stable URL: http://www.jstor.org/stable/1566901. Or: Rowe, Colin and Robert Slutzky. *Transparency*. With a Commentary by Bernhard Hoesli and an Introduction by Werner Oechslin. Basel, Boston, Berlin: Birkhäuser Verlag, 1997.

Figure 42. Beginner design students were asked to respond to paintings by capturing perceptually significant shapes and forms in eight different layers of drawings.



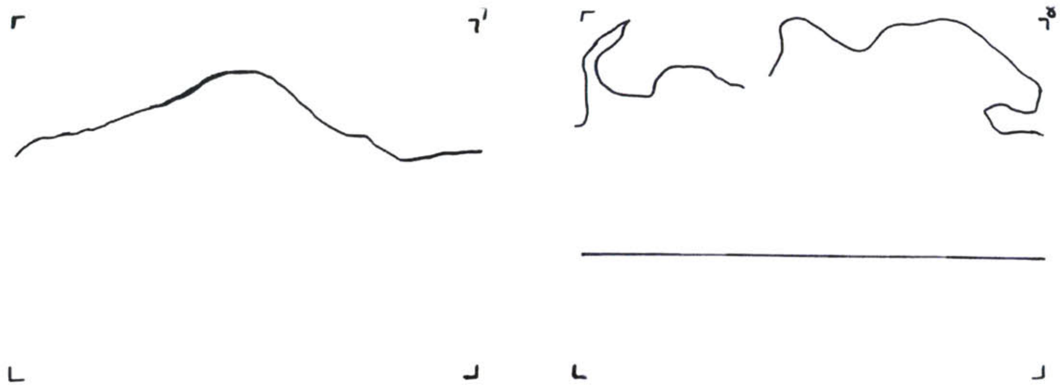
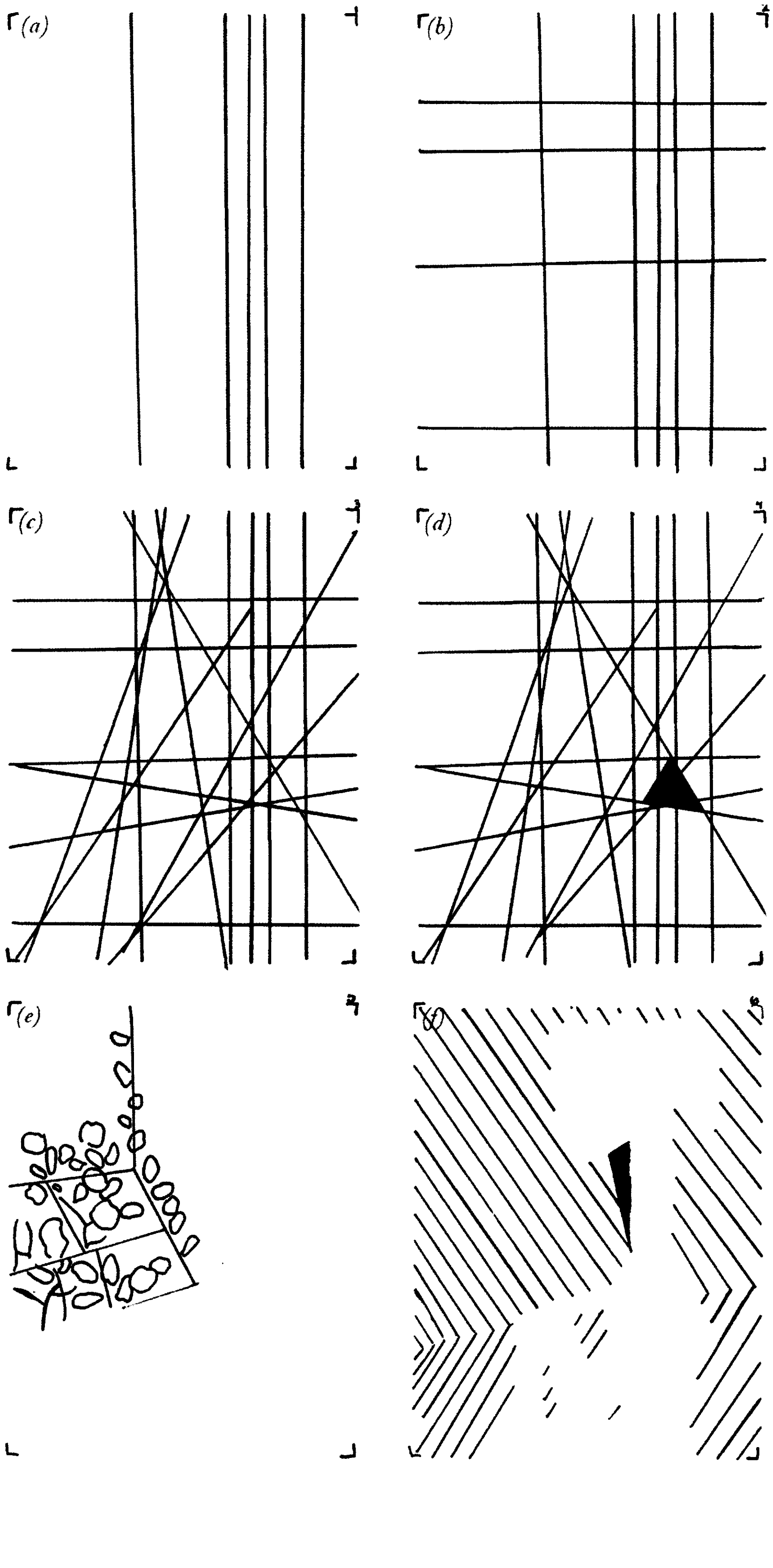


Figure 43. Drawings 43.a – 43.h *(from left to right)* are beginner designer Ozturk's eight-layer response to Cezanne's *Mont Sainte-Victoire seen from Bellevue* (1895), 2014. (Drawings are scaled. Originals were 9 inches by 12 inches.)

Figure 44. Beginner design students were asked to respond to paintings by capturing perceptually significant shapes and forms in eight different layers of drawings.


(a)
(b)
(c)
(d)
(e)
(f)

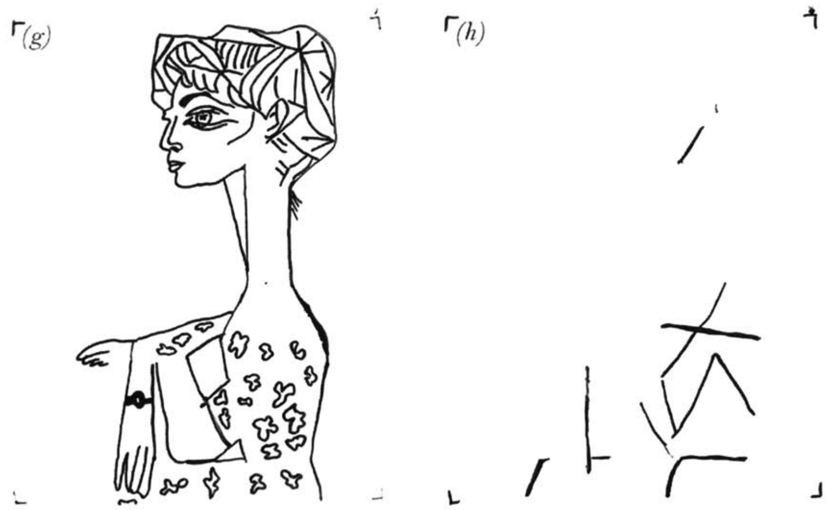


Figure 45. Drawings 45.a – 45.h are beginner designer Ozturk's eight-layer response to Picasso's *Jacqueline with Flowers* (1954), 2014. (Drawings are scaled. Originals are 9 inches by 12 inches.)

This exercise took significantly more time as compared to the previously applied tracing paper. Despite having the same instruction and objectives, having a set number of different layers of drawings drew students' attention to every step in an iterative process, and guided visual reasoning in significant ways. Firstly, seeing was slowed down significantly with the introduction of layers. Slowing down seeing forced more detailed sensory-perception, visual reasoning, deeper contemplation and deeper aesthetic experiences. Students increased their focus and talking subsided; self-conversation expanded and lengthened. Students contemplated intensely – drawing, redrawing, looking, seeing, and thinking. The exercise was thus successful in slowing down seeing and creating space for discovering different parts, wholes and relationships, along with making students focus on their visual reasoning.

The slowed down process shows us more intricate uses of visual schemas. One of the beginner designers in my class, Ozturk, for instance, used part relations $x \rightarrow prt(x)$ schemas and its inverse $x \rightarrow prt^{-1}(x)$ in order to analyze the structural lines of the painting as seen in drawings 43.a, 43.b and 43.c, and similarly in 45.a, 45.b, 45,c and 45.d. After discerning parts from the whole, the parts are completed to traverse the entire pictorial plane; using $x \rightarrow prt(x)$ and then $x \rightarrow prt^{-1}(x)$ repeatedly. The visual computational process looks like the generation of an irregular grid, going from simple to complex. The grid can also be described as the sum of lines that are generated from different parts of the x, x being the entire composition. For instance, 43.a can be described as the sum of $x \rightarrow prt^{-1}(prt_1(x)) + prt^{-1}(prt_2(x)) + prt^{-1}(prt_3(x))$; further drawings with more elaborate schemas.

In the layers, we can also observe the utilization of boundary schema $x \rightarrow b(x)$ and its inverse $x \rightarrow b^{-1}(x)$. In the drawings 43.e and 45.f, we see that planar tracings are explored. In the sequence of drawings, planes are captured in 43.e, then, with the schema $x \rightarrow b(x)$, the lines around the planes are explored. We observe a similar grouping in 45.f and 45.g; the main figure and its background are captured with different planes. Going from 45.f to 45.g, the main figure is outlined by taking the boundary of the figure plane and then detailed. Practices with boundary relations schemas and its inverses also aid explorations in figure-ground relationships, which is one of the foundational concepts in art and design.

4.4 Seeing Backward and Seeing Forward, Seeing New Shapes in the Moment

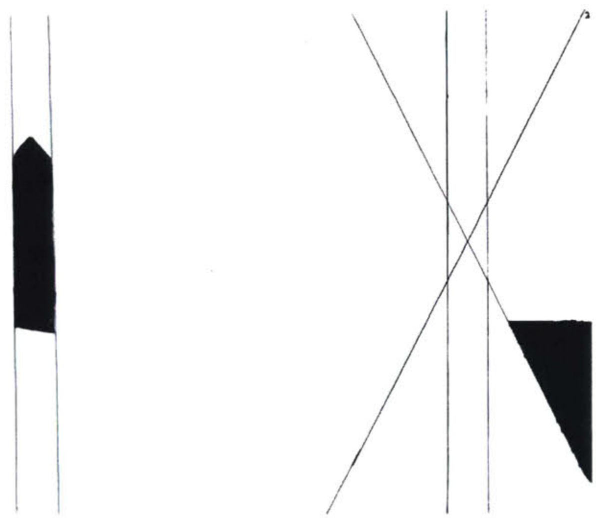
Having multiple layers of shapes creates an opportunity for students to use the layers and move back and forth in their design process. Our seeing can further guide our seeing and we obtain a productive cycle. We can always employ what we have done so far in order to inspire us in the next steps. In Silva's eight-layer response below, the step-by-step generation of a visual structural system is studied. He expressed the progression of lines as a computational process by adding lines to the previous design. He expressed that "he discovered lines as they stood out to him." Despite observing this process as "such a slow process," he added that "having a limited number of sheets helped [him] to pace [him]self." Introducing a limited number of layers or steps can really help students to pace their visual reasoning. Not having an unrestricted number of layers or steps can help beginner students develop strategies and heuristics without feeling lost or overwhelmed.

In fact, Silva also developed the heuristic that was based on his seeing and pace: he wanted to add "two more lines per layer." In each step, he was employing the visual schema $x \rightarrow prt^{-1}(prt(x))$ twice, observable in 47.a through 47.h. At one point in the session, he suddenly remarked, "I think I am going to use my layers [lines] to go back and look at which plane stands out to me the most." He began to use this visual structure composed of lines to go back and look at the previous drawings and the painting itself. After minutes of contemplation, the small exercise he devised for himself visually inspired him to capture one plane that "stood out to him." He also developed the visual reasoning of capturing "one plane per layer." As he went on, he kept inventing small games – like Habraken and Gross's notion of "concept design games"[112] – that continued to fuel his seeing, doing and interest.

While moving back and forth in the layers, he began to capture different planes that he thought visually stood out. This time, he was embedding parts in his already generated lines with the visual schema, using the part relation, then its inverse, then the part relation again; defining a recursive schematic function. He also recursively employed the inverse boundary schema $x \rightarrow b^{-1}(x)$ in order to fill in his planes in each step as well, obtaining the schema $x \rightarrow b^{-1}(prt_1(x)) + prt^{-1}(prt_2(x)) + prt^{-1}(prt_3(x)+(\ldots))$. Indeed, he had this insight of applying the same schema, but having different shapes: "It is very repetitive. [...] Doing a different thing each time, but doing the same thing." By the end of the exercise, he had also successfully developed the insight that as designers, we can become inspired by our own processes, and even collect material from our own previous steps.

[112] Habraken, N. John, Mark D. Gross et al. (Research Team.) *Concept Design Games: A Report Submitted to the National Science Foundation Engineering Directorate, Design Methodology Program.* Cambridge, Mass. : Department of Architecture, Massachusetts Institute of Technology, 1987. For Habraken's pedagogical vision for form-making and his progressive series of exercises, see: Habraken, N. John, Andrés Mignucci and Jonathan Teicher. *Conversations with Form: A Workbook for Students of Architecture.* London; New York: Routledge, Taylor & Francis Group, 2014.

Figure 46. Beginner students were asked to respond to paintings by capturing perceptually significant shapes and forms in eight layers. They also utilized their own drawings to go back, look again and see new shapes.



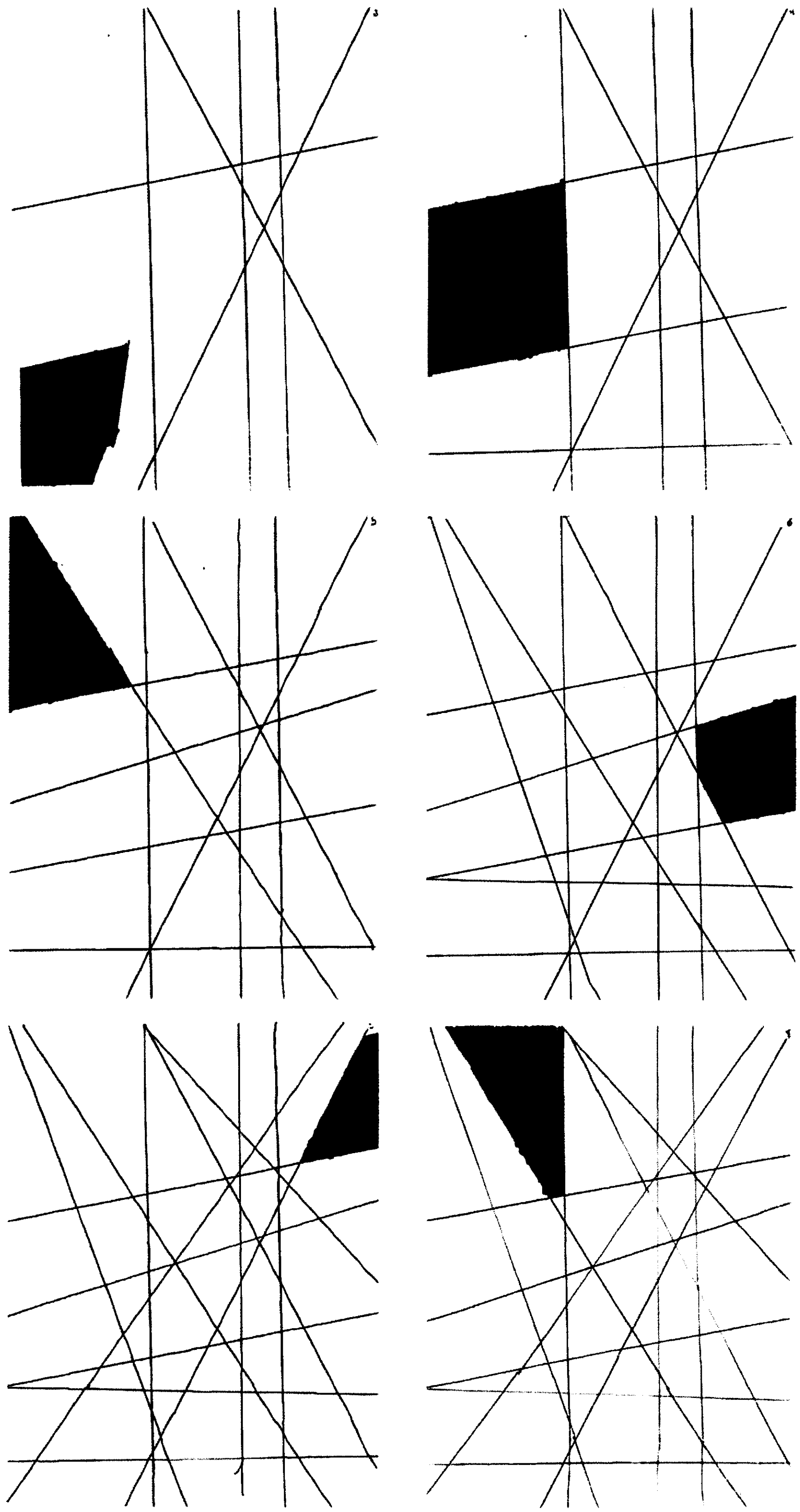


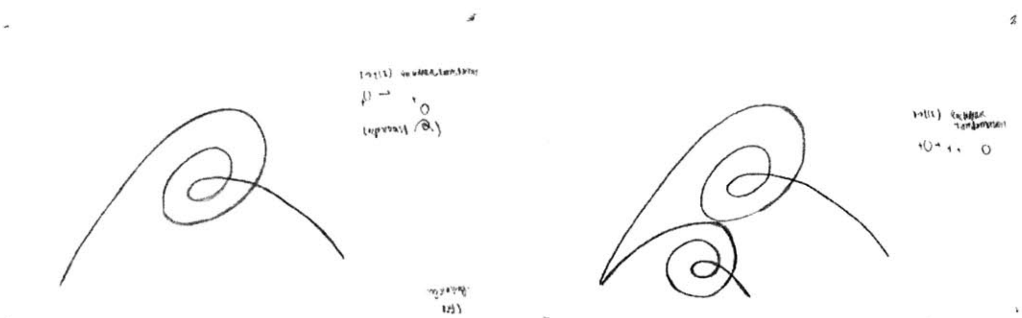
Figure 47. Drawings 47.a – 47.h *(from left to right)* Silva's eight-layer response to Picasso's Jacqueline with Flowers (1954), 2014. (Drawings are scaled. Originals are 9 inches by 12 inches.)

4.5 Talking in Visual Conversations

With exercises that focus on shapes and constructing spatial relationships, students progressively become more comfortable and skilled in seeing and doing. Step-by-step, they increase their fluency and literacy in visual languages. On one pictorial plane (canvas, paper) or across multiple pictorial planes, they have the chance to practice spatial and temporal relationships of shapes, forms and designs. They learn to sense, reason and talk with shapes – to have *visual conversations.*

The ease and fluency with which design students approach visual conversations are strong indicators of improved design understanding and design skills. The formal (form-based), visual-spatial (non-verbal) and procedural (process-centered) aspects of design were focused on in one of Habraken and Gross's concept design games "the Silent Game."[113] In the Silent Game, students are given different roles in an interactive design game, in which their exchanges are purely visual or spatial. They converse by one visual statement at a time – one rule application, for instance – on one ongoing design inferring meaning from the other's statements and answering the statement. This exercise is still assigned to the Design and Computation group students by Terry Knight and William Porter with great success in especially communicating that design is a computational process that runs on visual (spatial) rules and step-by-step perception, reasoning and action.

In one exercise, following the exercises *Seeing Fast-Slowly* and *Seeing Backward-Forward,* I applied an exercise of visual conversation that is inspired by the Silent Game. I followed my setup of the multiple sheets of tracing paper, emphasizing the procedural and conversational properties of visual design. Although students quickly came to a good understanding of this point, I was able to emphasize the purely visual and spatial nature of visual design reasoning. In this exercise, students were asked to form groups of two or three. They were requested to produce an original design on multiple sheets of tracing paper. Students were instructed to draw one visual thought or one visual rule on one page, in order to record their design process with rules. Furthermore, the students were told that they would be exchanging the designs with their partners at one point of the design process. Partners were to respond to and continue the other design process.

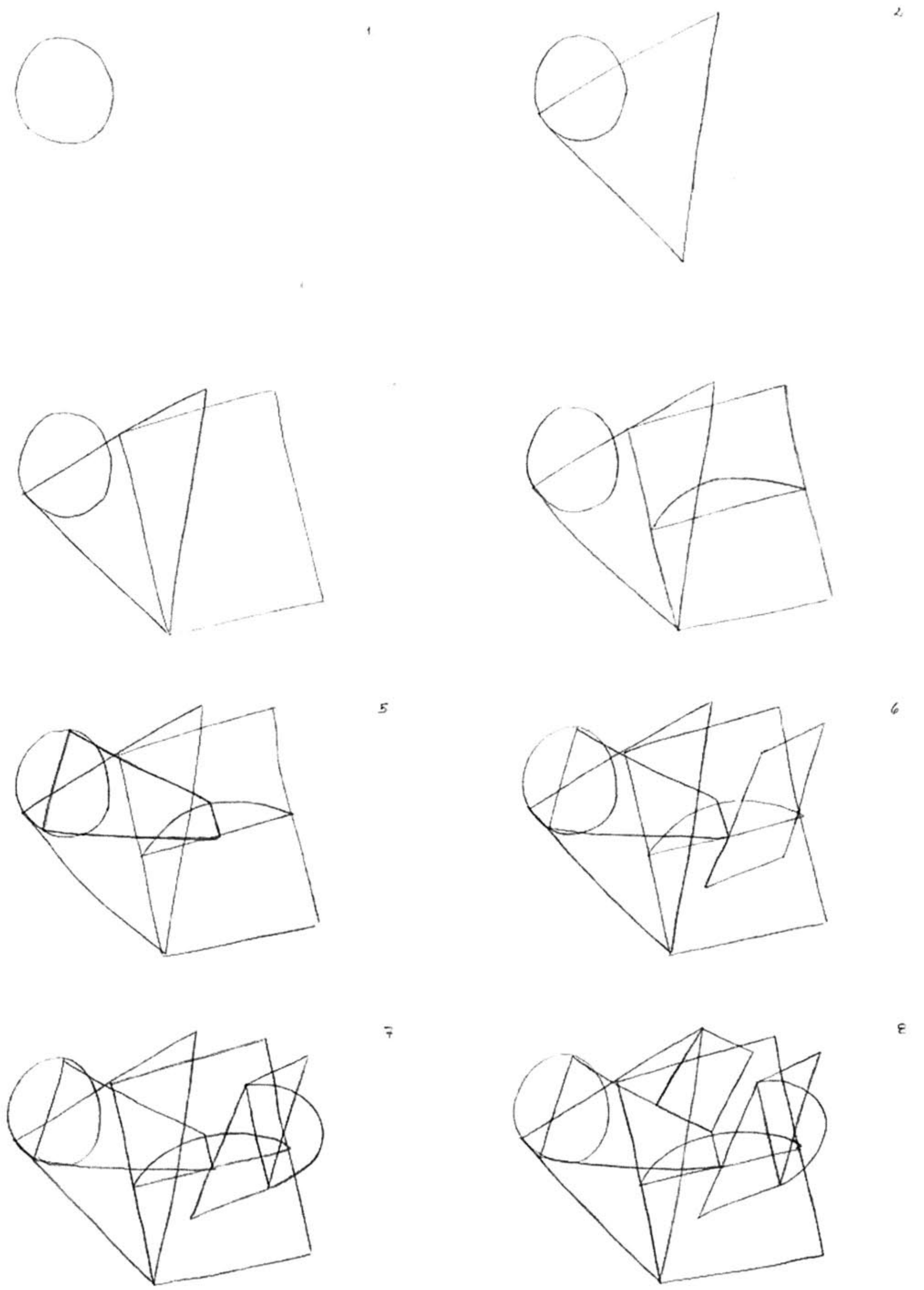


[113] Habraken, N. John, Mark D. Gross et al. (Research Team.) *Concept Design Games [Book II]: A Report Submitted to the National Science Foundation Engineering Directorate, Design Methodology Program.* Cambridge, Mass. : Department of Architecture, Massachusetts Institute of Technology, 1987.

Figure 48. Drawings 48a. – 48f *(from left to right)*: The start of a visual design conversation (conversation A), generated by one student, Singapore University of Technology and Design, 2013.

Given this prompt, some students chose visually more intuitive spatial relationships and progressions, while others chose more subtle and sensory-perceptually more obscure spatial relationships and progressions. In the example in Figure 48, the student essentially established one spatial relationship between two curling lines: two curling lines are always connected to each other at one boundary point. Using this rule, she advanced with parametric (or linear) variations of the curling line, as well as other geometric transformations. The schema for the composition is basically $x \rightarrow x + x'$; different linear (parametric) transformations of the curly shape x is recursively added to the emerging design.

In another example, in Figure 49, the student picked a very subtle but interesting rule: the new shape always makes use of a subdividing line that is associated with the previous shape and that always subdivides the previous shape into two equal parts. In other words, taking the shapes in a planar way, the student recursively employed the schema $x \rightarrow div(x)$ in order to generate a subdividing line. She went on to build this spatial relationship by assigning different shapes into the schema. The "subdivision into two" reasoning proved to be a very productive visual reasoning because it created the potential for seeing many new shapes. Then, she recursively utilized the inverse part schema $x \rightarrow prt^{-1}(x)$ in order to create a new shape – a polygon, which uses the line previously created as a part of it.



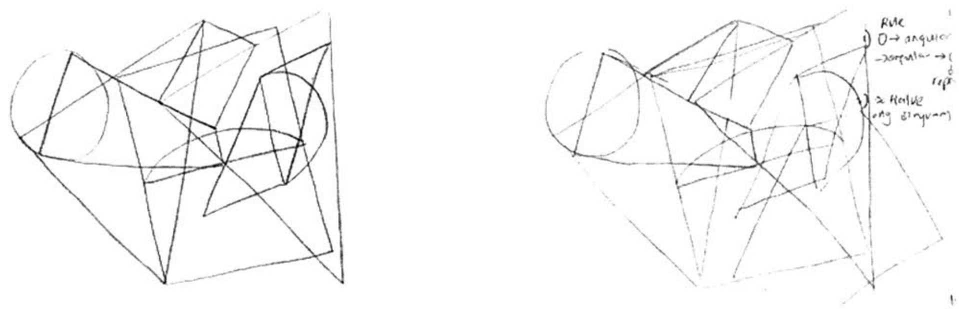


Figure 4.9. Drawings 4.9.a – 4.9.j *(from left to right)*: The start of a visual design conversation (conversation B), generated by one student, Singapore University of Technology and Design, 2013.

While this design exercise aimed at communicating the importance of visual reasoning, particularly through the application of shape embedding and visual rules, it also highlighted the conversational or dialogic character of a creative design process. Another function that the exercise had was to introduce the idea of a playful and game-like engagement with spatial-relational explorations. Student attempts at communicating their design logic to the other player highlighted the levels of control one could exercise over rules and processes; the potential for *misreading* or *misunderstanding* were increasingly understood as delightful – not frustrating – results of creative design. This exercise can be made more clear and precise by imposing limitations on the shapes, visual rules and number of steps in the computation. The exercise can also be left in a more open way for students to freely interpret what they see, how they write rules and how they visually reason.

In Aristotle's words, "Art completes what nature cannot bring to finish. The artist gives us knowledge of nature's unrealized ends." As studied in this chapter, seeing and embedding are what brings the human gaze, the artistic contemplation, the aesthetic experience into the world of visual, material and spatial stuff. As observed, shape grammar methodology systematically addresses this with every visual rule and visual schema application; as Stiny repeats, the shape grammatical approach to calculating is "phenomenal" and it "involves seeing." Indeed, it centralizes seeing and positions reasoning as a special case of visual reasoning. Its phenomenological and pragmatist approach allows us to capture any shape that we see in our design processes, leading to designs offering more possibilities in seeing.

As we have seen from the students' responses to these exercises, the basic visual schemas can be used next in the form of additions and compositions in order to explain more intricate processes of our visual reasoning. In the following chapter, I elaborate on the additions and compositions of visual schemas and hypothesize about how they document and guide our seeing. I continue to give examples from personal, class and workshop sessions in order to continue to address these questions: How do we talk about the subjective, personal and phenomenal experience of seeing? How do we place value judgments on the aesthetic experiences and the objects that give rise to them? How do we capture aesthetic experiences? Can they be formalized and recorded? How can beginner designers be educated so that they come to perceive and appreciate aesthetics? How can they gradually educate their discernments, appreciations, judgments and insights?

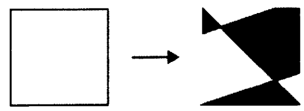
4.6 Seeing of and Seeing for: Picking Parts from Wholes and Creating New Wholes from Parts

In design studio pedagogy, exercises are often explicitly connected to each other, building on previous steps in order to realize more sophisticated designs toward the end of a project. Starting from basic abstract shapes and forms, students progressively build increasingly complex designs. For my experimental process, I also link each exercise and progressively, building on the initial exercises of responding to paintings and moving toward generating new designs by utilizing embedding, visual rules and schemas.

Figure 50. Beginner students were asked to respond to paintings by capturing perceptually significant shapes and forms in eight layers. They also utilized their own drawings to go back, look again and see new shapes.

Let's recall the exercise of responding to an existing composition – a printout of a painting – in a specified number of different layers of drawings on tracing papers and/or transparency sheets. In this exercise, students were asked to respond to the painting by capturing points, lines and planes that they see and determine as perceptually significant. They were given the same instruction "capture, draw and trace the design elements – like points, lines, planes and colors – that you see, that capture your eye, that you think is perceptually important, or perceptually and structurally significant for this design." Students were asked to produce eight different layers of visual information.

After this more open-ended visual exploration of shapes and forms, we can move onto a generative step utilizing the visual schemas explained in the previous section. One interesting way to go about this process would be to pick out a *visual unit* from one of our drawing layers. Then, we can use the schema $x \rightarrow \Sigma\, t(x)$ to investigate a number of options. We can again use our 2x2, 3x3, 4x4, 3x5 or other kinds of regular grids for this step. Once presented with this goal, picking out a *meaningful* "unit" to draw in an additive fashion, the way we look at and see our drawings is slightly altered. In other words, the way we embed, the way we visually reason through visual schemas $x \rightarrow x$, $x \rightarrow t(x)$ and $x \rightarrow x + t(x)$ change. Looking at one of the students, Tianna Huang's 8-layer responses to the painting and *seeing for* this purpose, we picked out a unit as such and wrote a corresponding visual rule:



We then used our unit in our visual schema of x $\longrightarrow$ Σ t(x), on a regular 4x4 grid. For the initial exercise, we stayed loyal to Euclidean (rigid) transformations, which are translation, rotation, reflection and their combinations – in other words, isometries. The sum of the transformations of x [$\sum$t(x)], wherein the transformation is translation, gave us the first design below. The sum of transformations of x, with a combination of translations and rotations, generated the second design. Starting from top left, the unit was rotated 90° in clockwise direction and translated. The sum of transformations of x, with reflections on vertical and horizontal axes, produced the third design.

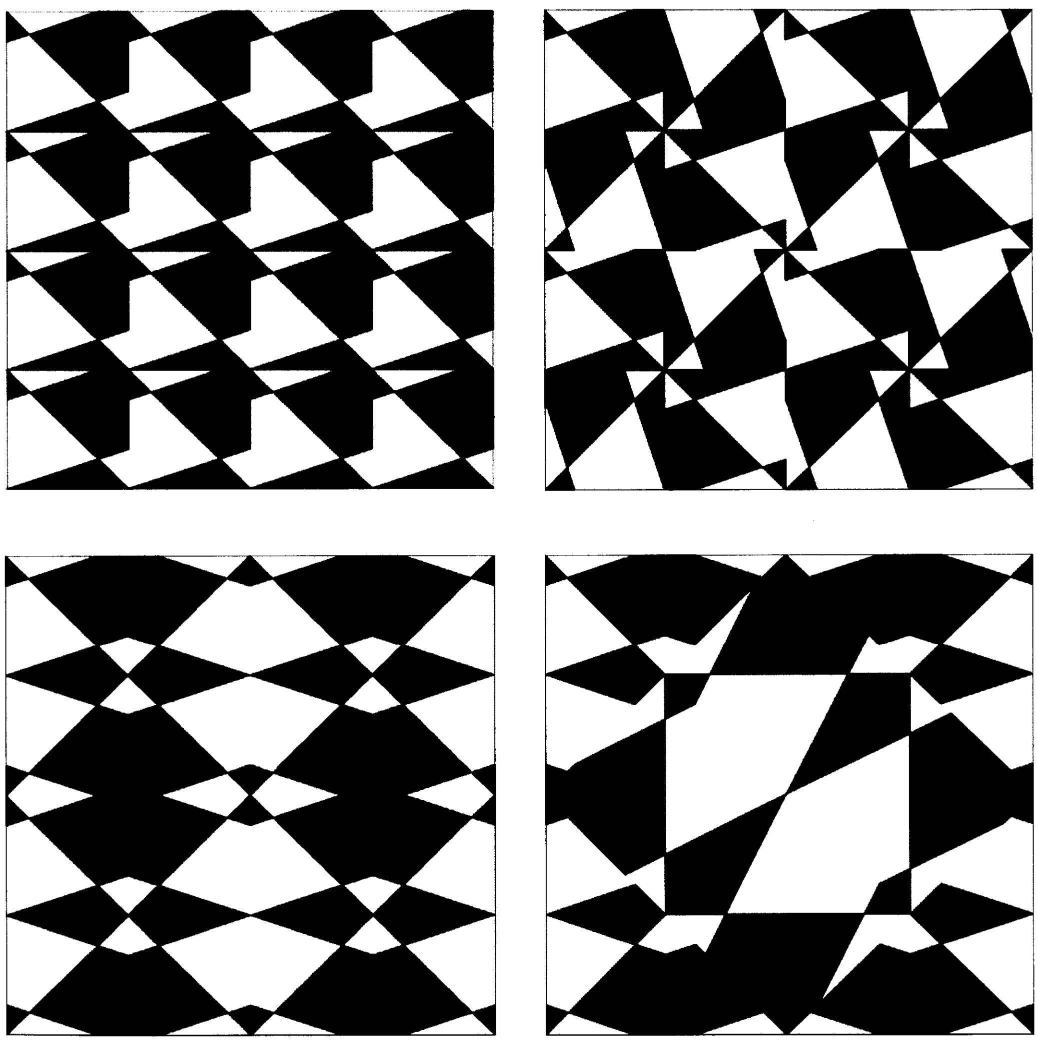


Figure 51. 51.a – 51.c are the designs generated from our visual rule and the visual schema x $\longrightarrow$ Σ t(x) applied on a regular 4x4 grid. Euclidean (rigid) transformations, which are translation, rotation, reflection and their combinations – in other words, isometries – can give us these three designs. Expanding our transformations to include linear transformations – like scaling – can give us more curious and complex designs, as in 51.d.

In the new designs, the original unit started to almost "disappear" and new shapes, forms and spatial relationships started to appear. In the first design, diagonals from top left to bottom right created new continuities and an alternative grid to the one with which we originally started. White quadrilaterals with six sides became repeating shapes, as well as black quadrilaterals eight sides. Alternatively now, I see the black quadrilaterals with six sides – rotated next to the white ones – and a black triangle adjacent to it. I also see upside down white triangles. The more I look, the more I see a greater population of parallelograms and trapeziums.

In the second design, I saw various integrated black and white pinwheel like forms. They were formed by seven sided quadrilaterals and triangles. I also saw new emergent squares and triangles of different sizes, sitting at 45°. Indeed, an alternative regular square grid appeared at a 45° angle. I now also see the same grid in the third design. In the third design, I saw many white quadrilaterals with six sides. Together with the white ones, I realize that I have an interesting moment of visual reasoning: I also see the black quadrilaterals as two six-sided quadrilaterals, overlaying each other in the middle. Since the forms are solid black, I cannot physically *distinguish* the overlaying intersection *per se*, but at the same time I experientially do.

Even in their relatively more limited repertoire for transformations, Euclidean (rigid) transformations are capable of giving us this *visual abundance* and *visual playground* to see, play, experiment, and explore. After basic visual practices with the Euclidean transformations, we can start expanding to linear transformations that can go beyond isometries. The most straightforward linear transformation is scaling and one that we indeed frequently use in visual design practices. Combined with Euclidean transformations, we can start exploring increasingly curious and complex design computations.

In the fourth design above, for example, linear transformation of scaling is utilized on our visual rule. In the third design, I observed an alternative regular square grid situated diagonally in relation to the initial grid. Once I see the four squares located at the center of the third design, I can apply my visual rule and visual schema of $x \rightarrow \Sigma\, t(x)$ as in the 2x2 regular grid. Since the grid size – or square size – is larger, I utilize a combination of translation, rotation (45°) and scaling on my top right t(x); then also used multiple reflections in my other t(x)s.

After picking out (seeing, embedding) a unit from one of their layers, student can continue generating new designs using our visual schema of $x \rightarrow \Sigma\, t(x)$, on a regular 4x4 grid. For this initial exercise, students can stick to Euclidean (rigid) transformations, which are translation, rotation, reflection and their combinations – in other words, isometries. Two sample student processes are shown below:

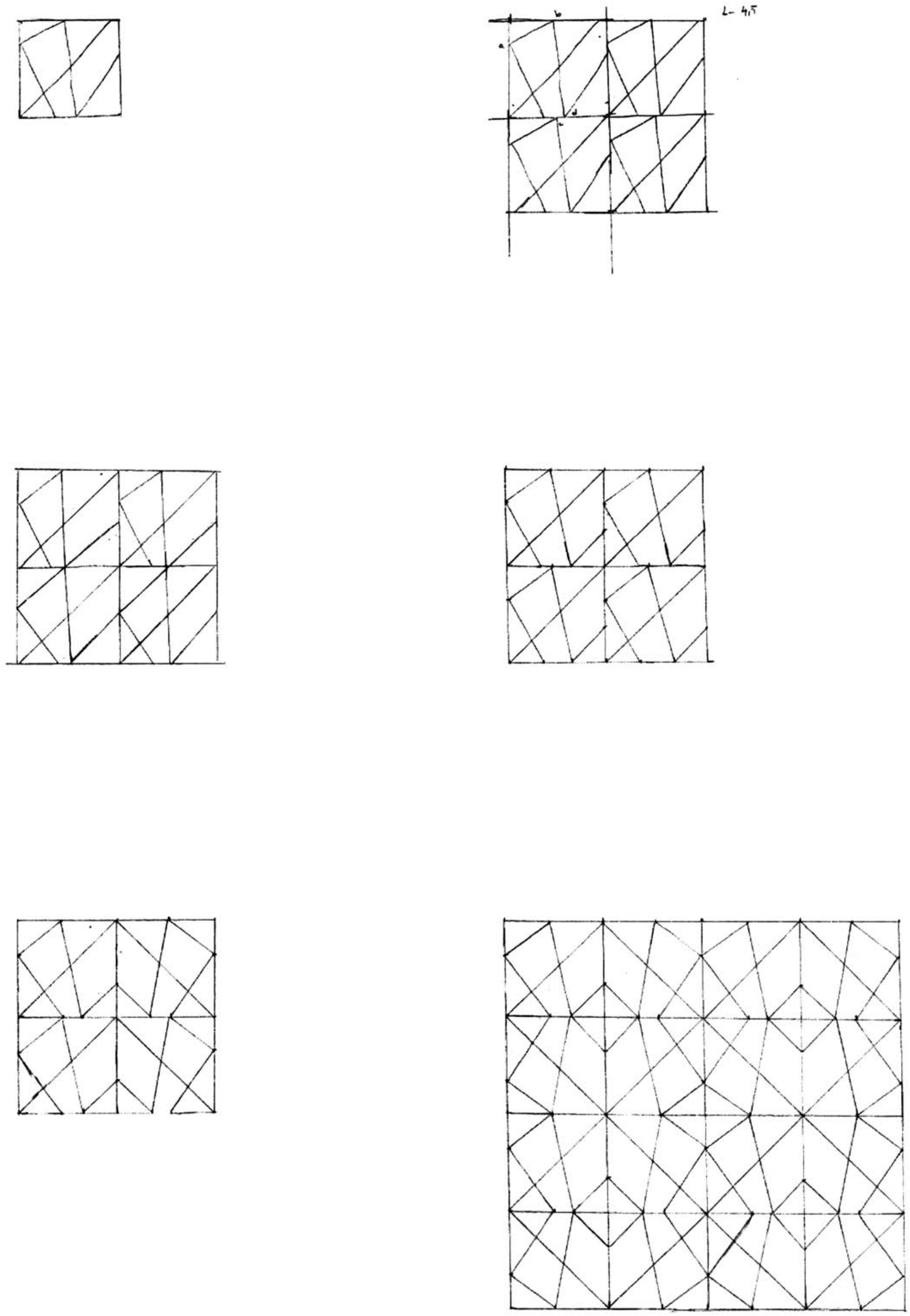


Figure 52. 52.a – 52.f are beginner designer L's design generation process, from picking a unit and practicing with the addition schemas, 2015.

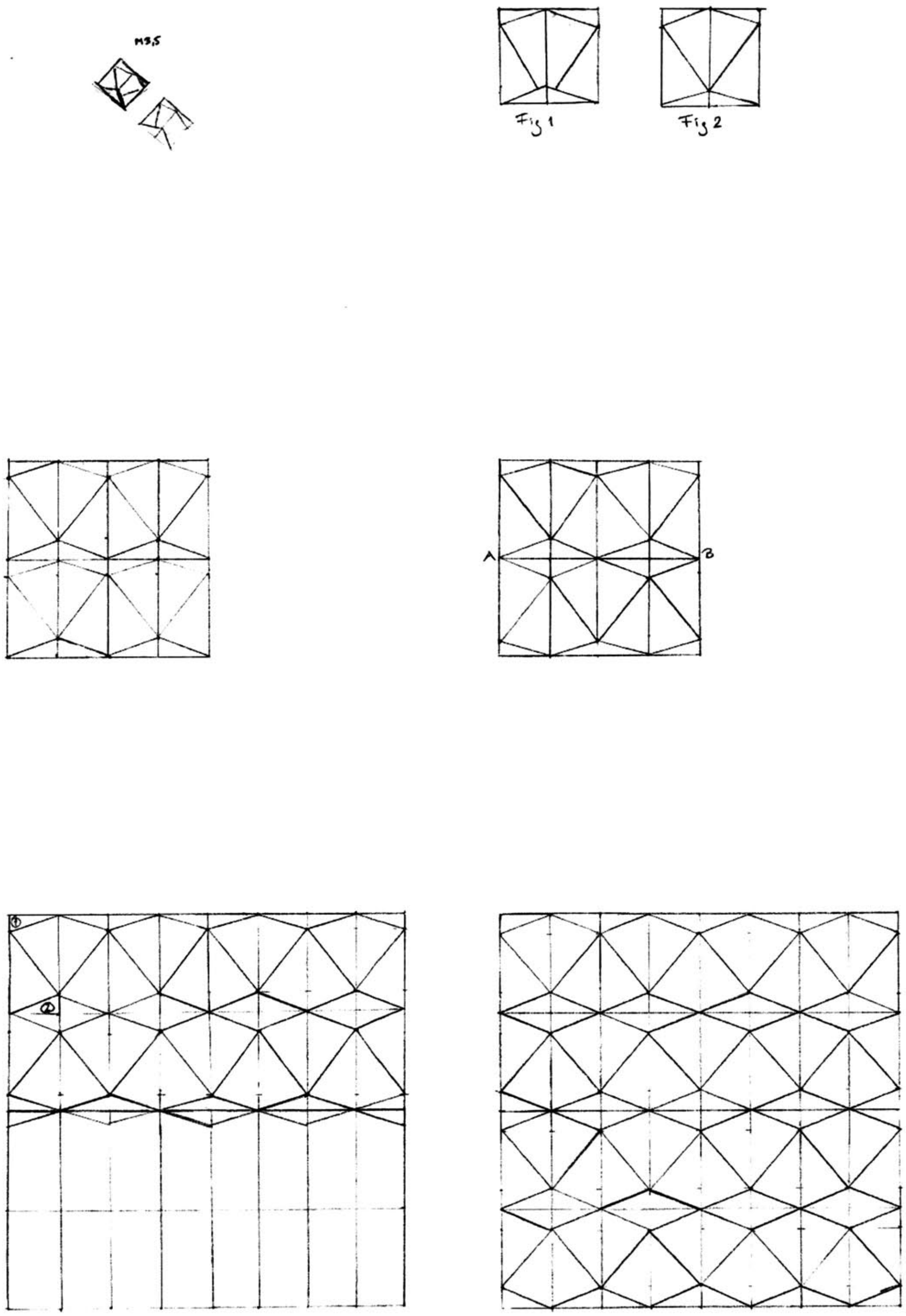
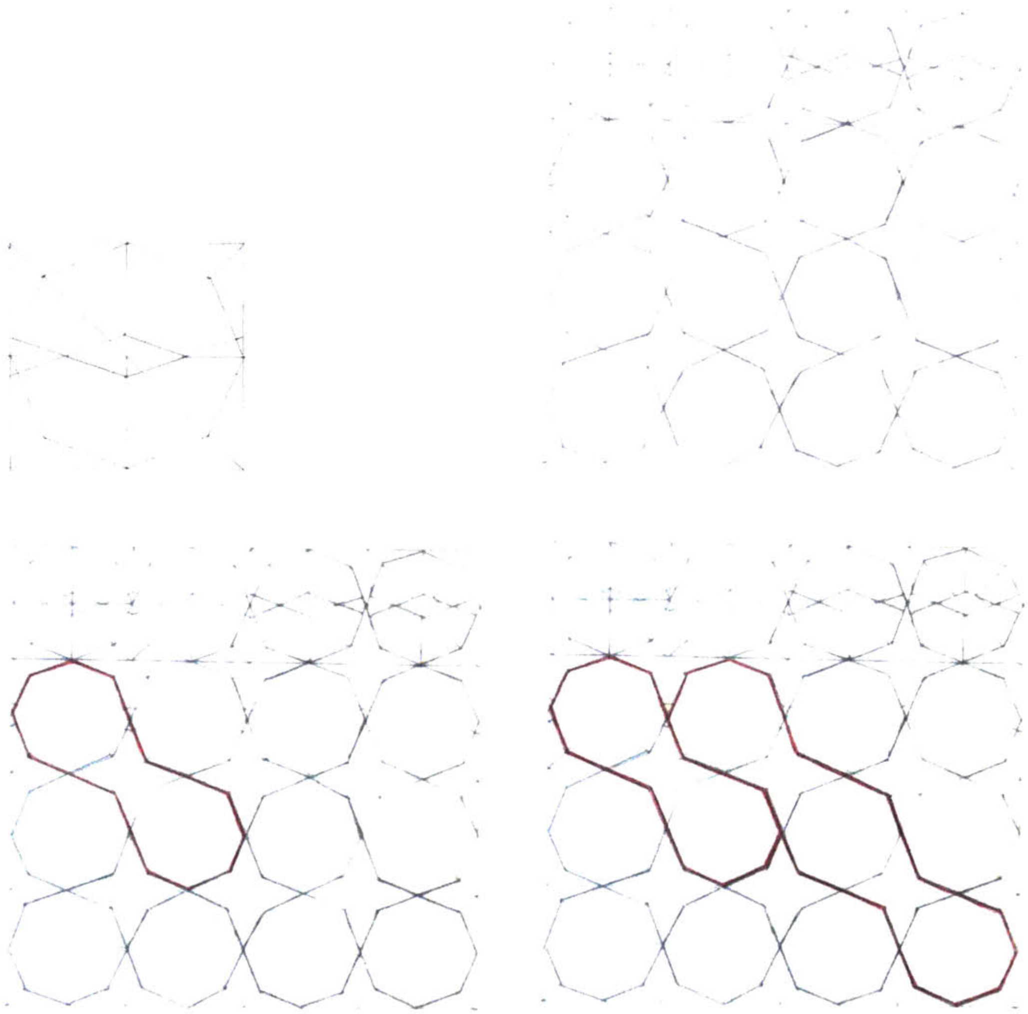


Figure 53. 53.a – 53.f are beginner designer M's design generation process, from picking a unit and practicing with the addition schemas, 2015.

Continuing from his previous designs in Figure 52.a to 52.f, beginner designer M reported becoming inspired by the interwoven octagons he was seeing. He decided to take that octagon and make it into a new unit. He then applied the assignment in the schema for our sum. While producing these designs, he kept responding to new shapes, which he decided to draw in different layers. He named the shapes "S" in Figure 54.c, "Sc" in 54.d, "octagons" in 54.e and "stars" in 54.f.



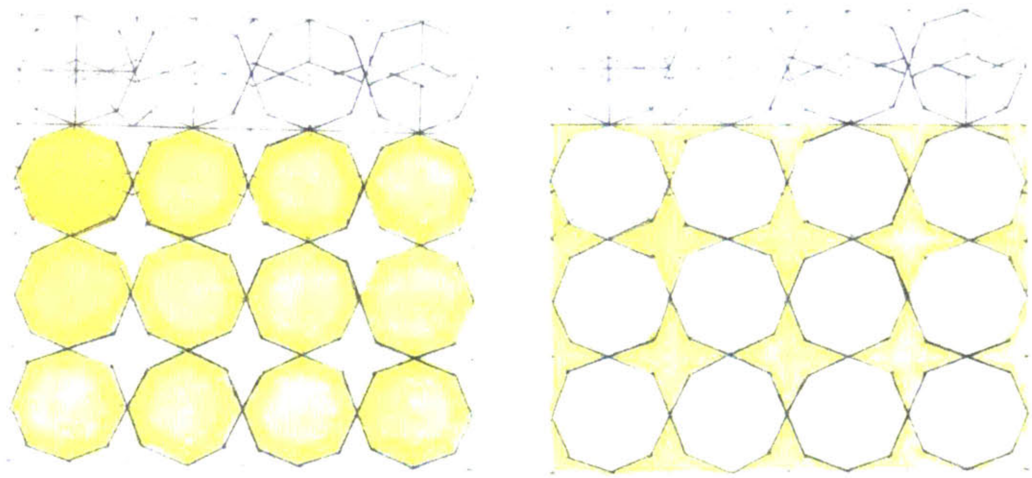
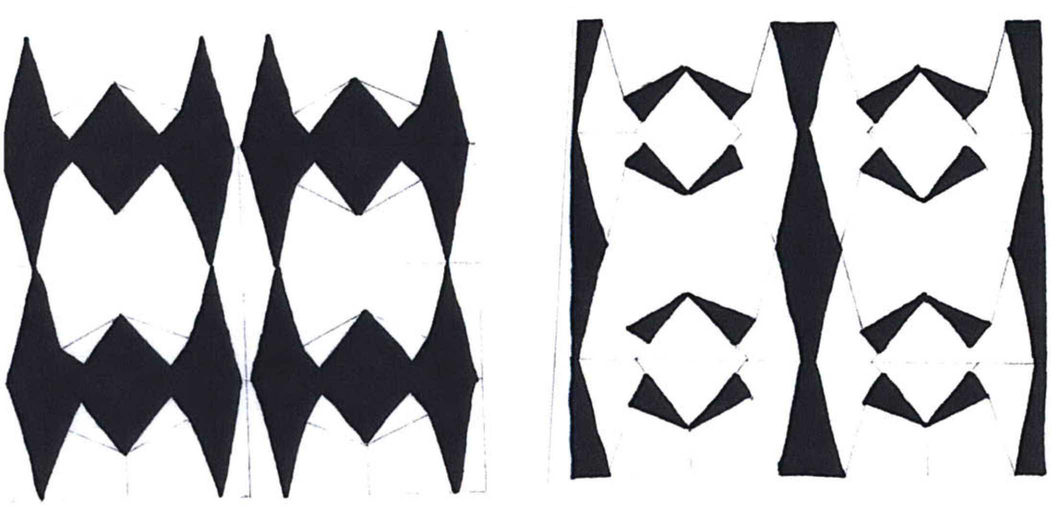


Figure 54. 54.a – 54.f are beginner designer M's second design generation process, from picking a new unit and practicing with identity and addition schemas, 2016.

This exercise can be advanced by starting to introduce planes and inverse boundary relationships, or alternatively weights. As seen in Figure 54, students naturally move towards coloring shapes and planes they like. Introducing black and white relationship, color and texture can be the next step to the visual practices with identities and sums. Different grid populations, different grid examples (i.e. triangular), or linear transformations of grids can be studied. Gradually, from two-dimensional organizational plane to three-dimensional organizational space can be investigated. Some examples of initial studies in black and white balance (notan), by applying the identity and inverse boundary schemas, are documented below.[114] These exercises follow beginner designer L and beginner designer M's previous steps in their visual experiments.



[114] Bothwell, Dorr and Marlys Mayfield. *Notan: The Dark-Light Principle of Design*. New York: Dover Publications, Inc., 1968.

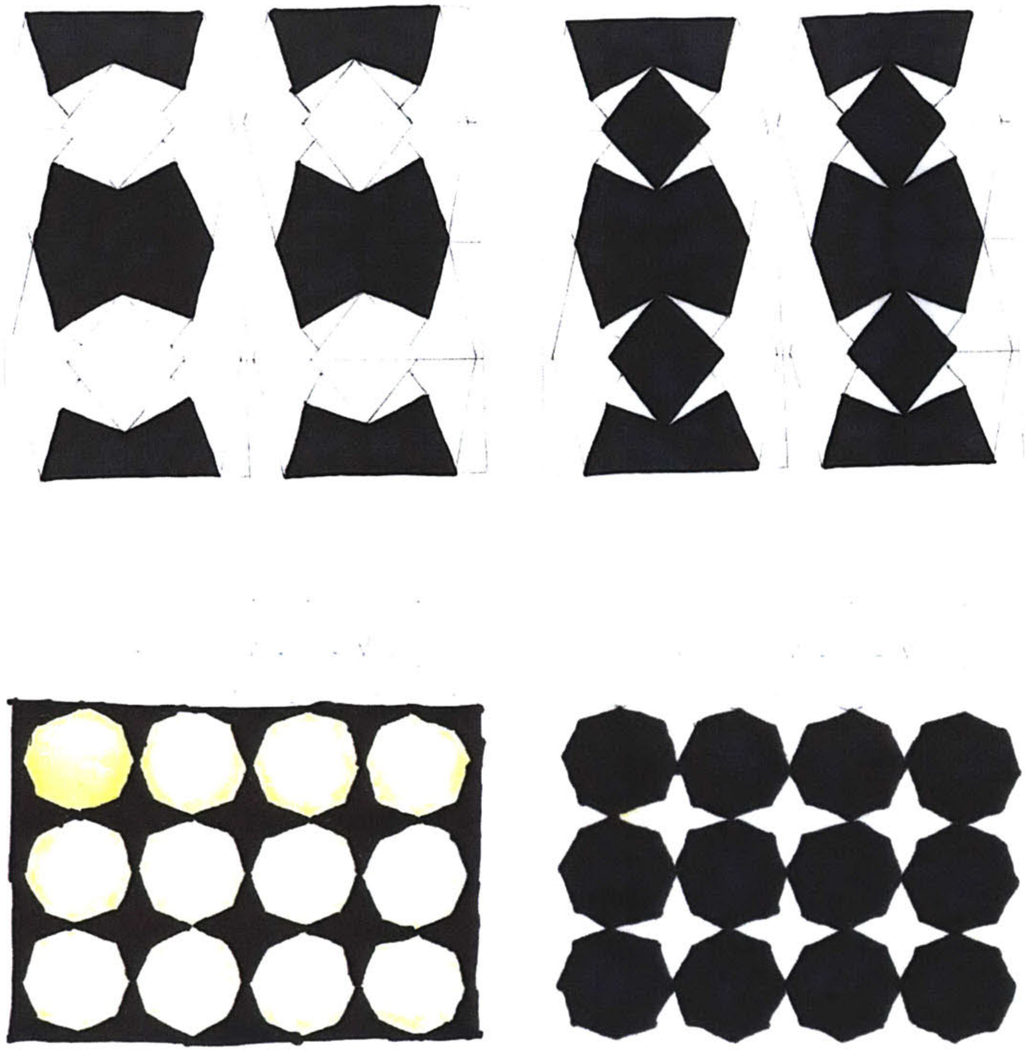


Figure 55. Beginner designer L and beginner designer M's visual experiments continue by building upon the previous steps. Black and white balance is studied through a perpetual application of identity schema and inverse boundary schema. Particular shapes are identified – embedded – and white or black planes are created by the application of the inverse boundary schema.

5 Conclusion

This dissertation elaborated on the observation that design studio discussions and directed conversations are often over-intellectualized while, at the same time, considerations on aesthetics are often either normalized or entirely overlooked in design education. While students may speak of their sensations and perceptions, and explain how they inform their decisions in the creation of their projects, these conversations are not credited as being truly important, especially in the official studio environment. There is neither an accepted *language* for deeper dialogues, nor an accepted philosophical ground and methodical tool for students to think with. Discussions on sensory and perceptual engagement often go unnoticed or are avoided altogether in formal critiques. These aspects of human experience – in contrast to rational thought – are considered difficult to formulate, to verify, to agree upon and to incorporate in meaningful ways; thus they often are devalued as a means for taking creative design forward.

Shape grammar theory and formalism straightforwardly address the phenomenal visual world and enliven our aesthetic lives through deepened aesthetic engagement. In the design studio, shape grammars and shape grammar-inspired exercises can guide students in their learning. They give students opportunities to observe their seeing, visual contemplation and visual reasoning. They allow students to organize their visual and designerly thoughts, especially those based on sensory perceptual and aesthetic experiences. Starting from *sensory-perceptual education* by repeated exercises in seeing, embedding and identifying, students can increasingly incorporate *formalist education* by also practicing with schematic descriptions: the intellectual – abstract – formulations of seeing, embedding, identities, transformations and other kinds of formal operations. As Holt puts it, "a knowledge of mathematical structures will help to free artistic expression."[115]

The studio exercises that I designed and developed here are primarily inspired by the shape grammarian notions of "seeing" and "embedding," visual rules and visual schemas, and have proven successful in helping students better understand themselves, their aesthetic sense and their design process. In correlation, I argued that if art and design are essentially a n-dimensional organization of elements on a spatial canvas in a certain arrangement or order, then aesthetic experience is the discovery – creation – of a multitude of orders by responding and observing. This experience can be recorded by visual explorations and visual computations, "putting into concise form the fruit of" our or "some other person's experience."[116]

In Chapter 2, I argued that understanding and teaching *visual design as computation* could revive and educate creativity in visual design by facilitating open seeing, "reasoning," appreciation for ambiguity (flexibility and changeability) and aesthetic experience. For this purpose, I traced the pedagogies of visual design computation in four core domains: a) visual design as aesthetics, b) visual design as language, c) visual design as science, and d) visual design as computation. Following the various understandings of design, I presented a number of dialectics in an effort to continue the rigorous yet fluid pedagogical vision offered by the design computational paradigm and shape grammar theory. These dialectics, which could guide design activities by offering new frameworks and gradients,

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[115] Holt, Michael. *Mathematics in Art.* London: Studio Vista; New York: Van Nostrand Reinhold Co., 1971.
[116] Sawyer, W. W. *Vision in Elementary Mathematics. (Introducing Mathematics: 1.)* Harmondsworth, Middlesex, England: Penguin Books Ltd., 1964.

included a) parts versus stuff, b) beginner versus experienced, c) shifting versus consistent, and d) embodied versus disembodied.

In Chapter 3, I described individual visual and visual schematic explorations in service of the pedagogical goals of developing skills in combining, composing, improvising and embedding in shape grammars. Starting with basic visual design sequences and corresponding operations with visual schemas, I explored increasingly more sophisticated uses of transformations, sums of transformations and dynamic sequences. I specifically focused on transformations, sums of transformations and dynamic sequences that seek to profit from seeing and embedding. I provided sample sequences of how idiosyncratic ways of seeing and improving awareness came into play in visual creative design and computation.

In Chapter 4, I elaborated on a number of sequential exercises that primarily focused on seeing and embedding. The results of seeing and embedding were captured in the form of multiple drawings by students. Observations and remarks were prepared by the author on the implicit uses of visual schemas. In seeing and embedding, particular emphasis was placed on fundamental visual schemas, which are the identity schema $x \rightarrow x$ used to embed and identify specific shapes that we see, the part schema $x \rightarrow prt(x)$ and its inverse $x \rightarrow prt^{-1}(x)$ used to pick out perceptual parts and wholes in our compositions, and the boundary schema $x \rightarrow b(x)$ and its inverse $x \rightarrow b^{-1}(x)$ used to see different kinds of shapes. During the course of these numerous exchanges, I developed useful heuristics both for students and for instructors, such as *"seeing fast and seeing slow," "seeing backward and seeing forward" and "seeing of and seeing for,"* and *"talking in visual conversations."*

At the very beginning of this enterprise, Stiny stated:

> It has been argued recently that the study of form itself should again become a central enterprise in architectural research and education. As March and Matela (1974, page 212) remark, "... a designer with a well-understood and structured vocabulary of form is more likely to find suitable matchings with functional requirements than one who attempts to let form follow function in some supposedly self-generative way." Of course, this view is justified only to the extent that knowledge about form can be obtained and taught in a scientific way.[117]

The call to make study of form a central enterprise in design research and education, echoed by March, is still relevant today, maybe even more so than it used to be.[118] As observed from what it elicited from students, shape grammars can help designers and students to access and cater their idiosyncratic ways of seeing and reasoning visually. Designers and students can develop their unique senses of shape, form and experience by practicing with visual shapes, visual rules and visual schemas. Shape grammar formalism provides students the "scientific" and computational structures to be able to keep conducting visual experiments. The continual experimentation develops their senses of creativity, aesthetics, and sharpens their abilities to wander off the beaten paths, and let their eyes/mind wonder.

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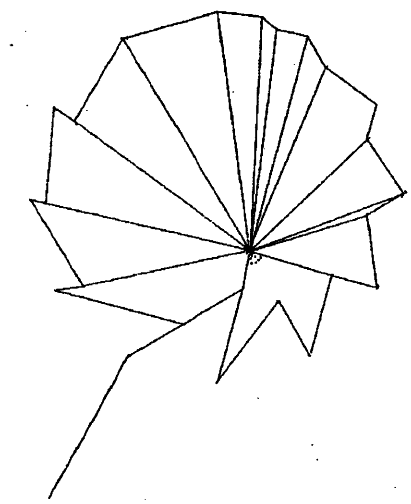
[117] Stiny, George. "Two Exercises in Formal Composition." *Environment and Planning B* 3(1976): 187 – 210. Also see: March, Lionel, and R. Matela. "The Animals of Architecture: Some Census results on N-omino Populations for N= 6, 7, 8." *Environment and Planning B: Planning and Design* 1.2 (1974): 193-216.
[118] March, Lionel. "Forty Years of Shape and Shape Grammars, 1971–2011." *Nexus Network Journal* 13.1 (2011): 5-13.

Following on the methods and pedagogical stance developed in this research, future studies will further integrate shape grammars and shape-grammar-inspired methods into design studio curricula and project-based design classes. Particular focus will be placed on students' and designers' visual reasoning, visual sequences and visual computations. Visual shapes, rules and schemas will be employed in visual experiments, both implicitly and explicitly. In my own teaching and practice, I will continue to investigate existing design exercises with the lens of visual shapes, rules and schemas. I will also explore new heuristics, both for students and for instructors, that build on the methods discussed here. In the end, everything is open to seeing again. The journey is not over!

Epilogue

Good luck to you in your visual explorations, computations and creations, dear *Shapesmith.*



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