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Chiu-Shui Chan

Style and Creativity in Design

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To Hungching, Dexter, Virginia

Preface

Design can be explained from two perspectives. One is from the action point of view that means to do something deliberately; the second can be seen as a product created intentionally by human beings to fit certain purposes. The first definition is the sequence and the last one is the result. Both are actually mental steps or cognitive results of going through sequences of manipulating various kinds of external information from sensory input and internal knowledge from memory, blending them together into an integrated one to create an artifact that satisfies certain requirements or constraints. The various sequences of these mental activities as they unfold in the designers' minds are called *design thinking*.

Studies in design thinking have been approached from areas of problem solving, human cognition, and information processing to explain how a design is cultivated, what methods are used by designers to create a design result, and how to precisely describe the formation of a design from its starting point to its end product. Many studies have been conducted and reported. However, there also are patterns of cognitive processes that trigger some phenomena in the processes and products. These phenomena, namely style and creativity, have been recognized as important factors coming from thinking and used to differentiate design stylistic patterns, classify typologies, and verify. In fact, these phenomena of style and creativity do correlate to each other to some extent, and it is crucial to know how the mind functions creatively and stylistically so that designers can improve design productivity. Yet, notions of the character of style and creativity, and their correlations, have not been systematically discussed in literature from the problem solving, cognition, and information processing points of views. This book serves these purposes.

How did this book come into being? It started in the years I was at Carnegie Mellon University. At that time, I devoted my efforts on the study of design methodologies used by master designers to strategically generate a design. I discovered that design is actually a problem solving sequence, which is operated by cognition. Thus, I took courses in cognitive psychology and tried to explore methods that could be used to study thinking. At that time, notions on association in memory network by John Anderson, parallel distributed processing in mental operation by David Rumelhart, and integrated cognition in cognitive architecture (SOAR) by Alan

Newell inspired me, thus, a number of psychological experiments were conducted to explore psychology in design.

The first experiment I did in 1985 was to study mental image and its internal representation applied by novice and expert designers. Results of the videotaped study showed that expert designers have a richer set of image repertoire stored more hierarchically in memory than novice designers. The rich set of knowledge schemata provides more opportunities for expert designers to quickly and easily combine images together, which explain why expert designers are more creative than novice designers.

The second experiment, conducted in 1986 through the use of protocol analysis, was to study how architects think while they design. In that study, a number of tasks had been carefully developed and applied including: formulated procedures of running the experiment for collecting protocol data, defined methods of coding and decoding verbal data; plus generated systematic techniques of transforming verbal data into a problem behavior graph. In fact, the exact methods of protocol analysis used for studying cognitive processes in design thinking had not been clearly published in detail around 1986. It took me awhile, with much trial and error, to develop the methods on data analysis. Fortunately, I had the opportunities to discuss the technical methods and procedures with the pioneers and forerunners in this field at Carnegie Mellon. Of course, that experiment fascinated me and I started to go further into the study of style.

In studying style, I explored the historical development of research in style. Then, I completed a case study in early 1988 on Frank Lloyd Wright's style to examine how Mr. Wright created his style. Late in that year, the concepts of operational definition, measurement, and recognition of style studied from the product point of view were set up, tested, and justified through four psychological experiments. In 1989, the seventh experiment on studying the creation of style was conducted through observing a successful architect's eight design processes in real time. Again, protocol analyses were applied to get first hand data for proving the hypotheses set up in the studies. It was intended to develop a cognitive theory of style in design.

After my teaching career started at Iowa State University, I was invited to guest lecture at a number of universities. During these years of teaching and research, the same experimental techniques were applied to concentrate on why some designers are more creative and stylistic than others, what cognitive factors generate both style and creativity, and what differences are between the two in results. After the eighth experiment on exploring design expertise, completed in 2000, I started to use other techniques of case study to further explore design thinking. Of course, five case studies after 2001 on a number of master architects showed evidences of the connections between the phenomena of style and creativity, which are discussed here.

Design is a skill and thinking is also a skill. We have to learn how to design and how to think. Likewise, we also have to learn how to generate an individual style and how to be creative. That is why this book intends to provide the knowledge and is what this book is all about.

Ames, IA, USA Chiu-Shui Chan

Acknowledgements

The fundamental part of the study that treats style and creativity as entities was done at Carnegie Mellon University (CMU) and further developed at Iowa State University (ISU). I was lucky to have a wonderful research environment at CMU, working with Omer Akin, John Hayes and Herbert Simon. I am grateful to Omer Akin for leading me through the exploration of applying psychology to architectural design. His critique on my concepts helped me shape the theory. His support on providing me with lab space and equipment was a great help.

I also want to thank Dick (John) Hayes for providing subjects from his psychology classes to make the experiments on the definition of style part possible. His numerous comments also gave me profound understanding on how to conduct good psychology experiments and how to analyze data. His wisdom and expertise on problem solving stimulated a lot of encouragement on my later study of creativity.

The late Herbert Simon was the one who influenced me the most—intellectually, philosophically, and spiritually. He introduced me to the area of models of thought through cognitive science. I learned from him that science is not necessarily independent of the fine arts. From him, I understand what scientific research is, while you expose yourself to the world of science. From him, I realized the meaning of the state of the arts. But, most of all, I learned from him what makes a good and respectable scientist—be able to grasp the insight into discovery.

I am greatly indebted to the subjects who participated in the seven series of psychological experiments done at CMU. Without their participation, it is impossible to collect the valuable mental data to justify the hypotheses developed that make the theory sound. Particularly, Richard Cleary, who participated in my study of the measurement of style and gave me valuable comments on my early study of Frank Lloyd Wright's Prairie House style. The other key subject provided me with a rich source of protocols. Leonard P. Perfido of L. P. Perfido Associates, an outstanding practicing architect from Pittsburgh, spent many hours in the college lab for a period of 3 months and deserves my special thanks.

The final theory of the study was developed and matured at ISU. I would thank my colleague, David Block, who attended my experiment on studying how designers' expert knowledge, which I termed seasonal knowledge, would affect design style. I must also thank students at the Architecture Group, Institute of Applied Arts, National ChiaoTung University (1997–1998), National Yunlin University of Science & Technology (2005), National ChengKung University (2005), and ISU for the many class discussions. Because of the talks and discussions, more thoughts on creativity and its connections to style were generated, particularly the "Design Thinking" course offered in the fall of 2011 at ISU, and at School of Architecture, Tianjin University, since 2011 to the present time. From offering the courses, I have the opportunities to refine, modify, and improve the theory and thinking in "thinking." I also want to acknowledge Jasmine Brown for her participation on the concept of repetition and offered her drawings to be included in Chap. 2, and Laurel Tweed for providing editing assistances for the manuscript. Supports from the ISU University Publication Endowment Fund 2011 and Faculty Professional Development Assignment Fund 2014 have made this book possible.

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Contents

Part II Style

Chapter 1
Introduction

Design thinking processes have been studied since the 1970s, exploring the intellectual phenomena that occur while designers practice design. These intellectual phenomena include the formation of intelligence, operation of knowledge, and actions taken for implementing design, which are the cognitive activities explored in the field of psychology. Recently, these cognitive activities that occur in design were recognized as a special cognitive domain with special behaviors, named *design cognition*. Design cognition focuses on the processes and psychological phenomena of how humans understand, process, formulate, generate, store, retrieve, and recycle design related knowledge that leads to the creation of a design. These design processes and cognitive phenomena are not only different from other thinking domains,[1] but are also unique forces that turn design conceptual schemes into physical artifacts. Behind these psychological activities, forces exist that create certain "recognizable features" in design products. These features are recognized through perception to categorize the product as an *individual style*. Due to the existence of *design styles*, outstanding design products can easily be recognized by the public as cultural symbols.

The household product of a tea kettle, designed by **Michael Graves** for **Alessi** (1985) and Target (1999), demonstrated that features of products could cause popularity and change the way Americans look at design in their homes. Other product designers followed the same style, and the kettle revolutionized small household object design. Thus, a design style has eminent power that drives culture and design patterns. In March 2012, ***Time*** magazine published the spring issue of *Time Style & Design*, introducing advances in art and architecture, interior and automotive design, and food and drink. The editor's letter highlighted, "*Style is not something superficial but something intrinsic. It is not gilding the lily but the lily itself.*" This issue

[1] In design domains, designers usually utilize mental images when designing. This media is the mental representation of design information. Operational methods of handling such a representation differ from operating different media; for example, symbols, whether abstract or numeric in computational domains, would be treated differently.

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displayed and illustrated the trend of modern style, and provided a lens to understand the cultural movements in style. Thus, it is the appearance of the lily that defines a style. Yet, the style discussed in this book is on how designers do design, what the cognitive activities are that create a style, and on how a style is recognized. As such, it is not just the lily itself, but on how a lily is created and identified.

Behind the psychological phenomena of mental activities and perceptions, there are other cognitive forces that trigger the creation of a unique design product. A unique design has the following characteristics: it is valuable, the act of creating it is original, and it is performed with special mental abilities that, in all, constitute creativity. Thus, creative products must be the work of initial and original creations. Outstanding creative works are generally treated as culturally influential, publicly recognizable, and socially beneficial products. Thus, creativity and style are two important cognitive phenomenon affecting design products and influencing civilization. If these cognitive aspects and causing factors can be understood, individual style and human creativity can be consciously improved accordingly, to improve design quality. For instance, the **Apple Company**'s digital products supervised by **Steve Jobs** are good examples. **Jobs** applied arts and aesthetics into engineering design, and insisted on simplicity for the user interface in Apple products. His way of design generated a style with an economical and unique appearance that dominated the market internationally. His style set a classic example for the fields of design, engineering, marketing, and management on how critical it is to think creatively. However, full studies on the cognitive factors that trigger style and creativity have rarely been completed. This book intends to explain the causal effects of individual style and creativity, approached from the perspective of design cognition and problem solving theory.

There are nine chapters in this book, concentrating on the study of the human thinking processes causing both style and creativity, approached from cognitive science. Methods used to discuss these two subjects have some differences. Studies on style focus on analyzing the stylistic features and factors that generate style. Studies on creativity focus on cognitive reasons generating creative actions in the design processes. Creativity research has moved towards the specific design methodologies used and specific factors triggering creativity, rather than to study the repetition of design patterns. Thus, the shaping of design representation, which is critical for design thinking, and its influence to creativity are covered more than style itself. This also is because representation has an indirect and intangible influence on style formation.

Chapter 2 introduces the historical development of design studies, concepts of design cognition, theories of problem solving, and all possible cognitive factors that relate to the generation of creativity and style. This chapter intends to set up the fundamental understanding of the studies in thinking approached from cognitive psychology, and outline all possible reasons causing creativity and style in the design process. Thus, cognitive patterns occurred, cognitive strategies applied, and cognitive mechanisms utilized in the design processes are itemized and concisely explained through examples. Particularly, the cognitive mechanism of repetition, which is the major factor causing style and rhythm, is explained by works done by

Alvar Aalto, and by a design project done by a student as evidence to explain the notion. Theoretically speaking, in order to study style and creativity relating to design thinking, it is necessary to have the following study items included: (1) to have a basic understanding on human cognition; (2) to develop a comprehensive picture of thinking behaviors; (3) to have some knowledge on the use of appropriate methods to study how human brains process information internally while solving problems in general and in design; (4) to formulate the causing variables; and finally, (5) to predict future possible research directions on design cognition. This introductory chapter possesses these research items that also serve as the purpose and scope of the beginning of this book.

Historically speaking, style has been treated as a part of arts. Its philosophical theory was also a part of aesthetical theory before the nineteenth century. Therefore, to serve as background knowledge, Chap. 3 covers the historical movements of research in art theory before and after the nineteenth century to explain the changes that occurred. The major art movements in the twentieth century are briefly discussed with representative images. Then, the historical movement of philosophical studies of style in various fields of music, painting, industrial, fashion, and architectural design are reviewed. Descriptions of the character of style after the Renaissance period and before the nineteenth century are covered for providing an overall picture of the historical theory of style. Only after the mid-twentieth century were studies on how styles are created from the designer's standpoint developed and proposed by scholars. These concepts of style, particularly individual style, approached from the design products and design processes points of view are clearly introduced in this chapter as well.

Chapter 4 explains the substantive nature of style through a series of four psychological experiments. By comparing the special style of **Prairie House style** by **Frank Lloyd Wright**, Modern style of **New York Five** by **Richard Mayer**, and **Vernacular style** by **Charles Moore** together with others in Experiment 1, the operational definition of how "features define an individual style" is proposed and verified. By comparing the number of **Frank Lloyd Wright**'s building designs by feature groups in Experiment 2, the strength of style within the same style is found from the experimental results. Results show that a total of three stylistic features appearing in a product is the lowest threshold for recognition. Equal or less than three features in a product is not recognizable as the style. Experiment 3 explores how many features appearing in a design product by **Wright** would be recognized as the **Prairie House** style. The concept of measuring a style is tested. This test confirmed that more than three features appearing in a product is the number for the style to be recognized. Thus, the number of features is used as a measurement scale. The data also shows that there are interactions among features; some features have higher weight for visual perception and recognition than others. Experiment 4 studies the similarity of features by testing their recognizability. If a feature is changed geometrically more than 40 % of its original shape, then it would not be recognized as the feature that goes to the same style, or it is not the same stylistic feature anymore. This could serve as an evaluation criterion for copyright declaration on determining the similarity between two images.

Chapter 5 explains how style is created from exploring the forces that caused the **Prairie House** style done by **Frank Lloyd Wright** from 1900 to 1910. This case study provides a clear illustration on the systematic methods used to recognize the repeated features that defined his style. Then, from studying the data collected from his writings and writings on him, a number of replicated factors including design constraints, methods, and rules are found. These found cognitive factors are further mapped with the repeated features to identify the correlations between the processes and features. **Wright** would repeatedly use a number of preferred features (no less than six), a set of design constraints, elevation grammars, grid and unit systems across his designs. Because of his constant application of so many factors that repeatedly created so many features, his **Prairie House** style is definitely strong enough to be recognized by viewers.

Chapter 6 explains the causes of style to see how style is created in design from the design process point of view. The study concept is similar to Chap. 5 on **Wright**'s style, but the study method was to run eight experiments in real time instead of using case studies. From the experiments, the cognitive patterns occurring in design that caused style were justified by protocol analyses methods on a famous architect in Pittsburg. It was found from the protocol data that the architect did repeatedly use some of his design grammars, developed from experience and his past design cases, into new designs. He had a certain set of preferred features that he would repeatedly apply. He liked to concentrate on the handling of light into spaces. But, because the features that appeared in the experiments were not strong, his style was regarded as a weak style. This chapter does explain the cognitive mechanisms that cause individual style. These three chapters construct a structured discourse on the nature of style (Chap. 4), the characteristics of style as seen from the point of view of cognition (Chap. 5), and how style is cognitively created in real time (Chap. 6). Results of these series of experiments provide a robust conceptual framework of the cognitive theory of style in design.

Chapter 7 covers the historical movements on the studies of creativity in various fields of social psychology, personality psychology, cognitive psychology, engineering, scientific discovery, education, and neuroscience to explore the trends of research done in this regard. In fact, the word *creativity* as it was used before the Renaissance period is not the same as it is understood in the modern sense. The concept of creativity, in ancient times, was treated as inspiration coming from mediators, i.e., Muses or divines, instead from the creators' consciousness. Only after the Renaissance was creativity recognized as humans' personal creation. Since the late nineteenth century, creativity has been studied scientifically, including studies on intelligence and the intellectual performance of eminent geniuses. Since the 1950s, psychological studies in creativity have been blooming. Scholars have set up the definition of creativity from various perspectives, studied the nature of creativity happened in everyday lives, explored the levels of creativity, discussed the methods used to assess creativity, and tested the methods for improving creativity in learning. All these notions on the studies of creativity are summarized in this chapter to set up a conceptual framework for design creativity.

Chapter 8 introduces the cognitive factors causing creativity in problem solving processes, and then they are analyzed by case studies. Four master architects' design projects, including **Frank Lloyd Wright**, **Otto Wagner**, **Renzo Piano**, and **Tadao Ando**, are used as examples for illustrating the concepts. Data collected from publications has shown the correlations between degrees of style and degrees of creativity to be in positive relations. **Wright** has strongest style and is the most eminent creator with the highest creativity, because his Prairie House designs create and display many features. **Wagner** has fewer features created and repeated in his designs, thus, his style and creativity are ranked second. **Ando**'s design has shown very unique creativity and style with a certain number of features created. His designs have demonstrated the application of the major factor of representation that causes unique style and creativity. **Renzo Piano**'s designs should be seen as a part of group style and group creativity, for his projects are mainly team works. From these case studies, the correlations between style and creativity in design are explained clearly.

Chapter 9 is the concluding chapter that summarizes the studies in thinking and cognition, and the cognitive mechanisms causing style and creativity. Following the summaries on cognitive operations that generate style and creativity, a number of methods on how to improve cognitive skill to improve style and creativity are proposed as a part of the cognitive theory of style and creativity. The theory defined is also verified by ecological validity to see whether the findings from the studies are extendable and generalizable to real world problems. Future studies in this regard, particularly in interdisciplinary cooperation with neuroscience, are briefly outlined as a conclusion of this book.

Hopefully, concepts explained through case studies and theories developed from psychological experiments in this book should provide inspirations and stimulations to professional designers and academics in design related fields. Parts of the concepts explained in Chaps. 4, 5 and 6 have been briefly discussed in the journals *Design Studies*, *Environmental and Planning B: Planning and Design*, and the *Journal of Architectural and Planning Research*. But, this book provides comprehensive and thorough descriptions on the cognitive theory of style and creativity. Future studies will be conducted to further verify a number of details provided in this book, which will be published in both English and Chinese language versions.

Part I
Conceptual Framework

Chapter 2
Introduction of Design Cognition

2.1 Definition of Design

Design is the human conception and planning of virtually everything in the world. All man-made design has as its fundamental essence that everything is driven by certain intentions and is accomplished by a series of actions to generate results. Design is process, artifact, and discipline. As explained in the American Heritage dictionary, to design, seen from the action point of view, is: (1) to conceive or fashion in the mind, invent; (2) to have as a goal or purpose, intend; and (3) to create or contrive for a particular purpose or effect. Synthesizing these definitions into an integrated conceptual framework, design can be described as to conceive a purpose, contrive a goal, and formulate a plan for a purposeful intention in the mind. On the other hand, design seen from the perspective of an entity, is: (1) a drawing or sketch; (2) a graphic representation; (3) a particular plan or method; (4) a reasoned purpose; or (5) a deliberate intention (American Heritage Dictionary 2013). Here, a purpose and an intention are both treated as entities, for they are the products of creative actions. Thus, design is a created object, a generated method, a developed purpose, or a conceived intention for everyday routines conducted through mental efforts. Design should be recognized as an essential part of human life—in fact, a critical component of human intelligence—and, as such, deserves critical discourse.

If looking at design from the fields of making artifacts (e.g., architectural, graphic, fashion, industrial, interior, and engineering design, to name just a few), design can be defined specifically as *all human creative endeavors of shaping objects to meet purposes or constructing a structure adapted to objectives, which require professional consideration on aesthetic beauty, functional uses, social symbols, and market demands and supplies*. All these endeavors can also be seen as solving certain problems with satisfactory solutions. Thus, to make the long definition short, design can be seen as *human endeavors of creating satisfactory solutions or beautiful artifacts to fulfill certain functions*, which explains the essence of design

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activities—the intellectual creation of feasible solutions or aesthetic artifacts—and these creation efforts must be devoted to meeting functional requirements. This explains a part of design thinking.

In fact, an astounding array of design products are created by designers and shared and used every day by the public. Constant use of any product has dramatic impacts on many aspects of human life. These product impacts are causal effects from design and by design. For instance, usability provided in household products will impact users' productivity (Norman 2002). Phenomenon of patterns created in building forms will yield different perceptions in the built environment to the beholders (Holl 2006). Color and materials used in working environments will affect human cognitive performance (Chan 2007). Since the impact of design products influences our well being and everyday performance, a comprehensive understanding of design, especially design thinking, would help to explain how design is generated to improve design ability and enhance design products. Indeed, design thinking is a part of problem solving activities and is an ability that can be utilized in the creation of artifacts and for other everyday tasks. Techniques used in formulating and solving design problems can also be used to solve relevant problems in our own lives.

2.2 Design Thinking and Cognition

If we see design as a series of mental activities generating entities, then we should see these activities as intellectual processes, the parts of human thinking operated by consciousness. In cognitive psychology, *thinking* is defined as the phenomena of human cognitive operations. Thus, *design activities* can be defined as thinking activities executed by cognitive operations. On the other hand, design products could also be seen as the physical results coming from the design thinking process operated by cognition. Thus, whether interpreting design from the process or from the product point of view, the bottom line is that design is created by human cognition.

For decades, scholars have studied the nature of and attempted to define *design thinking*, which has been considered a "way of thinking." Peter Rowe was the first one who used the term in the title of his book, *Design Thinking,* to explain problem solving procedures used by architects and urban planners (Rowe 1987). From combining numerous scientific studies conducted in various fields, a clearer picture has emerged and the term ***design cognition*** used to categorize the activities that occur in the design process. Design cognition has gradually been developed into a discipline. For instance, the nature of design cognition has been studied through looking at design from the computational (Cross 1999) or problem solving perspective (Cross 2001). Chuck Eastman used the term to refer to the study of human information processing by using different theoretical and empirical paradigms to describe the process of design information (Eastman 2001).

Given the rapid development of new technologies and new study tools available, it is prudent to re-examine and rethink this topic to incorporate new scientific developments occurring in other related fields. This chapter takes this new approach by looking at the conventional studies, rethinking the methodologies applied, reviewing the directions, and suggesting a new approach, particularly from the architectural design perspective. Once design cognition is well defined and fully understood, it is appropriate to analyze how designers stylistically and creatively do design, and identify the causes of style and creativity that occur in the design process.

2.3 Development of Design Studies

If *design research* is defined as a scientific approach to design or regarded as a study approached from the scientific perspective, as **Herbert Simon** explained in his theory of the "Science of Artifact" in 1969, then all the works done through methodological and rigorous sequences by artists in their creative processes or by scholars in their studies should be recognized as design research. In his book, Simon proposed that a science of design is a body of intellectually tough, analytic, formalizable, empirical, observable, and teachable doctrine about the design process (Simon 1969). Thus, all design works performed by a system of inquiry procedures can be taught, recorded, and studied. Artists, in their creation processes, are researching the ways of creating artifacts through implementation and execution, which can be duplicated. Scholars, in studying artists' creative processes, explore the various methods used for creation and expect to summarize the knowledge of creation that can be learned and replicated. Therefore, both artists working systematically on creating a work of art or a craftwork, and scholars on studying how a designer thinks or creates a design, should be recognized as conducting design research.

Following this premise, the geometrical perspective drawing method, developed in the Fifteenth Century in Florence as Quattrocento Art (Hartt 1994), is a result of design research. The use of a physical model to represent design, such as the scale model of the Basilica of St. Peter's, founded by the Emperor Constantine, should also be recognized as design research. However, the modern development of design research with a systematic approach only traces back to the works done by the **De Stijl** group in the beginning of the twentieth century (Cross 2000). **De Stijl** (Dutch term for "The Style") was a movement led by architect **Theo van Doesburg** in the early 1920s. Their design principles were based on functionalism with the following characteristics: (1) using rectilinear planes in the way that is similar to slide the planes across one another; (2) eliminating decoration on surfaces; and (3) limiting color schemes to pure primary hues together with black and white. Their works had clear principles and procedural routines to follow, which were the tendency of methodological approaches of the time on artistic creation. Because these rules and procedures were followed by a group of artists and designers in various design fields, their creation endeavors are recognized as the beginnings of design research that applies scientific principles to systematically arrange design composition.

Bauhaus, the school of Art and Craft, also incorporated concepts around 1920 from the **Arts and Crafts Movement** in England to develop structural concepts in their design curriculum. By integrating arts and science and combining crafts and practice, Bauhaus, led by **Walter Gropius**, created a new direction for architectural design education. They emphasized the honest and direct use of materials as the most functional path to design. At Bauhaus, students were required to take craft courses as well as painting, drawing, and theoretical studies in design and color. Faculty at Bauhaus also conducted research on mathematical and representational analysis of the concept of how sensations were organized into a unified perception, which was the "field" theory developed by **Gestalt psychology**[1] (Wertheimer 1923). **Paul Klee**, the Swiss artist who joined Bauhaus from 1921 to 1931, utilized the rules of organizing patterns to explore sensation and perception in his course materials (Teuber 1973). In the period from 1920 to 1930, scientific methods for exploring design emerged, which became a discipline, and was termed *design studies*.

During the two world wars (1914–1918, 1939–1945), the war activities drove the need to automate production. They resulted in mass production of bombs, ships, and weaponry. Equipment in factories used by the war industries were thus of the highest possible level of sophistication at that time. All the rest, for example, housing, food, or transportation was in need of mass automation after two world wars. So mass production during the world wars was set as an example to drive automation in civil industries. Thus, studies in design started to focus on mechanical efficiency to improve the performance of products. However, an individual designer had limited ability to handle the increasing complexity of the industrial manufacturing of products. Thus, methods of production through systematic design procedures became the research focus. In the post war era, the shortage of labor required technological development on mass production and product automation. Labor issues, together with the swift transformation from military wartime equipment to civilian demand for consumer products required the development of new production methods in manufacturing. For instance, in industrial design, studies began to utilize systematic methodologies in design around 1950 to make processes more efficient and effective.

From 1950 to 1960, design studies were mainly influenced by system theory and systems analysis on design, which set up the basis for a "**design method movement**" (Cross 1984). The system theory and analysis were coming from well-developed information processing theory and operations research, which inspired scholars to study design methodology. At that time, design methodology was regarded as a prescribed and rigid approach to design. This movement called designers' attention

[1] Gestalt Psychology involves recognizing how sensations are organized into a united perception by human beings. Its major concentration is, in vision, on understanding how the whole is different than the sum of its parts while we are perceiving things. The major concepts of this theory are that the perceiving behavior of an object is determined by the spatial-temporal configuration of the objects in our visual sense. Because of the good understanding of the phenomenon of perception, it has big influence to the fields of industrial design, painting, graphic design, and typography after it is developed from 1920 to 1930. Details of the notions applied in design are explained in Chan (2008).

towards exploring systematic design procedures, and proposing systematic methods for designers to apply. Two classical examples presented in the first Conference on Design Methods, held in London in 1962, attracted designers' interests.

The first classic example is the works of **J. C. Jones**. Jones, as an industrial designer for a manufacturer of large electrical products in the 1950s, applied **ergonomics** as a means to understand the design process of engineers on designing electrical equipment that better responded to user requirements. When his ergonomic studies found that the engineer had not considered user behavior, he redesigned the engineer's design processes to respond to the human requirement first, and the machine requirement second. A procedural sequence applied in design to allow intuition and rationality to co-exist was called *design methods*. Other than generating and utilizing design methods in the design process, Jones proposed that the design process has cycles, or stages of analysis, synthesis, and evaluation. The analysis component is the problem analysis stage that requires making all design requirements on a list, and carefully studying their interactions to make a set of logically related performance specifications. The synthesis stage is to find solutions for each specification and build up an integrated design solution with the least conflict among the specifications. The evaluation stage is to test the accuracy of each alternative solution in order to select the final one. The processes could be recycled and repeated whenever necessary (Jones 1963). He described these three essential stages of design in simple words as "breaking the problems into pieces (analysis) … putting the pieces together in a new way (synthesis) … and testing to discover the consequences of putting the new arrangement into practice (evaluation)." The purposes of his study were: (1) to reduce the amount of design error, re-design and delay; and (2) to make possible more imaginative and advanced designs (Jones 1963, p. 63).

In architecture and urban design, **Christopher Alexander** (1964) developed a "**pattern language**" methodology, which serves as a second classic example from the 1960s. The fundamental notion of pattern language was to solve design problems through combinations of selected design patterns. To Alexander, a language had vocabulary, a collection of named solutions to problems, called *design patterns*. The conceptual framework was that our built environment included the geometry of physical objects, which was a 3D embodiment of a culture, and an organization of social institutions defined by human activities. The human activities were used to categorize the social institutions and be anchored in spaces. Thus, spaces categorized social institutions that attributed to human activities. For instance, categories of space inside a house embodied the culture of its family; whereas the categories of space in a city embodied the culture of the people in the city. Different environments had their own morphological laws given by the acts made by builders, and the formations of acts were guided by the combination of the builder's mental images. Such combinational systems of images were exactly, to Alexander, like human languages. These systems allowed a person to produce various combinations, and every environment was formed from such combinatorial systems of images representing patterns, much as in combining words in languages. That is why Alexander called such systems "Pattern Languages" (Alexander et al. 1977).

The patterns in pattern language correspond to the rules of grammar in natural language. Each pattern is a fluid image that can be combined with other patterns. In all, patterns can be described as the overall layout of a building, ecology, large-scale social aspects of urban planning, regional economics, building components, structural engineering, or building construction. The rules of grammar and their meaning in pattern language systems are not given predigested. Every designer can generate and share his or her own language. Then, shared languages gradually evolve towards greater and greater wholeness. To **Alexander**, the good patterns would spread widely; the bad patterns would eventually drop out. Therefore, the environment so created by designers, though changing constantly, were as coherent, whole, and real, as a totality. In 1996 at an Association for Computing Machinery (ACM) Conference, he reinforced that the purpose of a pattern language is to create morphological coherence in the things that are made with it.

The definition of each pattern in the language, explained by **Alexander**, includes a problem that occurs over and over again in the environment. A solution to this problem is described so that it can be used many times without solving it the same way twice (Alexander et al. 1977, p. X). Following this definition, each pattern has the following standardized format:

1. A picture shows an architectural example of that pattern.
2. An introductory paragraph sets the macro context of the pattern by explaining how it helps to complete certain larger patterns.
3. A short format of a headline with less than two sentences explains the essence of the problem.
   *** (Three diamonds mark the beginning of the problem)
4. The body of the problem describes the empirical background of the pattern, the evidence for its validity, and the range of different ways the pattern can be manifested in a building.
5. The solution part describes the field of physical and social relations that are required to solve the stated problem, in the stated context. The solution is stated instructionally on what is needed to do to build the pattern.
6. A diagram shows the solution with labels to indicate its main components.
   *** (Three diamonds show that the main body of the pattern is finished.)
7. A paragraph ties the pattern to all smaller patterns needed to complete this pattern, to embellish it and to fill it out.

Therefore, pattern language consists of problem statements explaining the problem context, solutions of the problem with rules embedded, a sketch diagram showing the solution schematically, and contexts to combine the solution with other patterns globally and locally. Table 2.1 is a general outline of patterns. An example given in *A Pattern Language* (Alexander et al., p. 854, pattern 184) on a cooking layout that could be located in a kitchen (pattern 139, p. 663) is simplified in Table 2.2. Figure 2.1 is a diagram showing the cooking layout solution (p. 856).

As shown in the format, we can present the problem statement component as X describing the context of the pattern, Y is the solution, and Z is the problem to be

Table 2.1 Format of patterns

Format of a pattern (problem):
1. Example picture
2. Introductory paragraph, global context
***
3. Problem headline
4. Problem body
5. Solution grammar
6. Sketch diagram
***
7. Links with other patterns, local context

Table 2.2 A cooking layout example

Name:	Cooking layout pattern #184:
Pattern context:	Within the Farmhouse Kitchen (#139), or any other kind of kitchen. The character of a good kitchen comes from the arrangement of the stove and food and counter
Problem:	Cooking is uncomfortable if the kitchen counter is short and also if it is too long
Problem statements:	The best arrangement for a kitchen design is the one that saves the most steps; and this led to compact kitchens. These compact layouts save steps but don't have enough counter space. Studies have shown that there is insufficient counter space in many kitchens
Solutions:	To strike the balance between the kitchen which is too small, and the kitchen which is too spread out, place the stove, sink, and food storage and counter in such a way that:
(Rules:)	1. No two of the four are more than 10′ apart
	2. The total length of the counter – excluding sink, stove, and refrigerator – is at least 12′
	3. No one section of the counter is less than 4′ long
Solution context:	Put the pattern with Thick Walls (#197), Sunny Counter (#199), Open Shelves (#200)

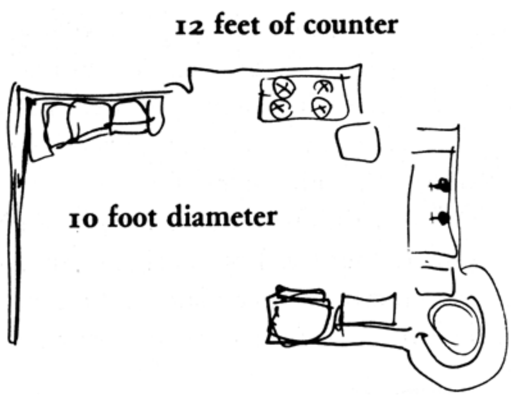

Fig. 2.1 A diagram of cooking layout (Source: Image was adapted from *A Pattern Language*, 1977, page 856 by Alexander et al., Oxford University Press)

resolved. Yet, the most essential nature of the language is the various contexts associated with the problem Z and solutions Y. Contexts X are not only paired with problems, but also are required to be considered in the solution syntax. For instance, the larger context of the cooking layout pattern is in the farmhouse kitchen (pattern #139) or any kitchen area, whereas the solution contexts are that it will be in the working surface of sunny counter pattern (#199), thick walls pattern (#197), and/or open shelves pattern (#200). While designers apply the patterns in design, various combinations can be generated due to the flexible rules provided. In execution, the format of the language can be seen as an hierarchy of parts, linked together by patterns that have a carefully defined set of design rules for solving generic recurring problems associated with the parts.

A famous example given by **Alexander** to explain the method of running the language is the Indian village design, published in 1963. In that example, he observed the problem context, made a list of 141 design requirements, then studied these requirements by pairs and determined by graph theory through computer programs whether they were dependent or not. The interacted pairs of requirements were further connected by links and grouped into twelve subsystems, which were combined further again into four major subsystems. The set of requirements and the set of links together defined a linear graph that served as a complete structural description of the village. Of course, each subsystem had its diagrammatic concept to show their images (Alexander 1963).

Pattern language has had a big influence on design education. Many scholars have discussed its applications in studio teaching, but there also are concerns that: (1) the problem situation encountered by the designer might be different from the given context (X), but the designer might pay attention to the factors of the problem situation that are similar to X and assume the same solution Y, rather than to dig into the problem further; and (2) the context (X) may not be an accurate representation of the situation reflecting the relationship between the solution (Y) and problem (Z), thus solutions might be misguided (Lang et al. 1974). Despite concerns expressed in the field of design, pattern language concepts have influenced other fields, because the notion of pattern languages helps problem solvers to tackle the complexity of systems through patterns; for example, it shares the same notion in object-oriented work on patterns in computer science. Each object in the **object-oriented programming** (OOP) paradigm has context, problem, and solution, many of which can be shared and evolved as entities. Thus, after the original publications in design fields, notions of pattern language have since been applied to the fields of software engineering (Gamma et al. 1994), computer science (Buschmann et al. 1996), software design (Fowler 2002), and user interaction design (Tidwell 2005).

Similar studies done in the 1960s and 1970s on developing procedural techniques to be used in design to systematically manage the progress of the design processes include work by **Bruce Archer**. Archer developed a model to illustrate a systematic method for solving industrial design problems (Archer 1965). He indicated that a design had six sequential stages of: (1) receive brief, analyze problem, prepare detailed program and estimate; (2) collect data, prepare performance specification, reappraise proposed program and estimate; (3) prepare outline design proposal(s); (4) develop prototype design(s); (5) prepare and execute validation studies; and (6) prepare manufacturing documentation. These stages logically covered the design from the beginning to the ending stage. Within the process, there were 227 activity items formulated in a completed checklist for product designers to consider. These sequential stages, to him, were sometimes overlapping, sometimes confusing, and sometimes required returning to early stages when difficulties were found. He explained that the art of industrial designing was essentially the art of reconciling a wide range of factors drawn from function, manufacturing, and marketing. In design practice, some projects were quite complicated, and involved contrasting skills and a wide variety of disciplines. Therefore, designers must make some assumptions or judgments, which might not be supported by collected data. Under such circumstances, any proposed design solution that constituted a hypothesis based upon imperfect evidence had to go through tests of the marketplace, or an indirect feasibility analysis, before it was completed (Archer 1965). Archer also used management science and operations research with logic operations to frame the overall structure of the design process that fit textile, clothing, jewelry, ceramics and interior design. The essence of the overall structure of the design process was in applying a reiterative problem-solving operational model to a goal driven system that was appropriate to the design problem (Archer 1970). Archer's studies have shown the influences of problem solving theory and operational research, in addition to the characteristics of systematic methodology.

This 1960s–1970s period, categorized as the **methodological approach to design** (Cross 1984), generated a number of studies on design methodology, yielding significant results on exploring the steps to complete a design. A number of special groups were also formed. These groups, including the **Design Research Society** (founded in London, 1966), **Design Methods Group** (in Berkeley, 1967), and **Environmental Design Research Association** (in North Carolina, 1968), have hosted conferences and published conference proceedings or newsletters since 1962 (Cross 1984; Bayazit 2004). Researchers in this period mainly concentrated on observing design experience and phenomena occurring in the process. Through observing these phenomena and from applying simple mathematical diagrams and flow-chart type models, certain patterns and structures in the design processes were analyzed and reported descriptively. However, these approaches were criticized as merely studies on the general interpretation of design logic or on general explanations of processes. These methodological studies disenchanted professional practitioners. Scholars were also aware of the weaknesses of these approaches (Archer 1979). Interestingly, **Alexander** indicated that design methodology would not help design because it lacked the motivation for making better buildings (Alexander 1971). Similarly, **Jones** also rejected design methods and changed his research direction (Jones 1977). Thus, first generation design methods were not capable of handling the complexity of real-world problems.