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初探設計類比思考之三種現象–傳統媒材與數位媒材

Three Phenomena of Analogical Thinking in Design

Conventional Media vs. Computer

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中 華 民 國 九 十 七 年 九 月

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中文摘要

類比思考在設計領域中一直扮演著重要的角色，設計師常會轉化其他領域的事物作為靈感的來源。然而在設計領域中目前尚未有一套完整的類比思考理論，其理論多半引用於其他領域。此外，設計類比思考在過去也一直與傳統媒材中的手繪做連結，鮮少探討其他媒材發展類比思考的可能性，例如近來最常被注意到的電腦媒材。因此本研究針對設計思考的議題，並從媒材的角度出發，去探討兩個問題，其一，設計領域中類比思考的共通性；其二，在傳統媒材和電腦媒材中類比思考過程的差異性。為了達到這個研究目的，本研究分成數個部分，包含邀請受測者完成兩階段實驗、以口語分析結合視覺資料來分析數據、最後提出三種現象。從實驗中的三種現象中瞭解到類比思考是一種設計者、類比來源、設計目標、和媒材的互動關係，設計者在這個過程中扮演最重要的角色，他們可以決定並轉化他們有興趣的來源，而設計者的設計能力和創意力也決定了類比的深度。媒材在這過程中扮演輔助的角色，意謂媒材可以間接的改變設計過程和設計結果，媒材本身的特質更讓類比思考過程有更多變化性。此研究結果希望對於設計領域研究設計師設計思考議題有另一個方向的認識。但因本研究為初探性質的研究，所以所選用的受測者人數較少，在未來的研究中會邀請更多設計者的參與，做更廣泛的類比思考的研究，並期望提出一套設計領域類比思考的模式。

Abstract

In this research, the author proposes three phenomena of analogical thinking in design. Analogy has been ascribed a key role in the architecture design. Until now, there is no a complete theory describing how analogical thinking process works in design domain. Moreover, analogical thinking always relates to freehand sketches and rarely connects with other medium. Therefore, this research attempted to investigate the analogical thinking from the perspective of design media. Two purposes in this research are to study the common points of analogical thinking in design field, and the differences of analogical thinking process in conventional media and computer. In order to achieve the objectives, there are three parts consisted in this research including two phases of experiment, analyzing the data and addressing three phenomena of analogical thinking. According to the results of analysis, analogical thinking is an interaction between designers, analogical sources, design target, and design media. Designers play the most important role in analogical thinking process because they can choose and transfer the idea which they are interested in. The analogical depth also depends on the designer's imagination and creativity. On the other hand, the design media play a supporting role in analogical thinking process. It means that the characteristics of design media not only affect design process and design result but also offer the variability of analogical thinking design. The contribution of the research is a preliminary understanding of analogical thinking in design field. The limitation of the research is owing to few numbers of subjects and still no theory describe how analogical thinking works in this field, the author use the common research method of investigating design process. The research discusses some phenomena of analogical thinking in design field. Our further study will focus on broad approach of analogical thinking and offer a framework of analogical thinking process.

謝誌

在我研究所的兩年，我經歷了很多風風雨雨，而這本論文是我兩年最後心血的結晶，也許不夠完美，但是卻是一個巧妙的終點，也是我展開研究生涯的起點。在這過程中，一直在支持我鼓勵我幫我加油給我最好的建議的劉育東老師，我要對您致上最高的感謝和敬意，沒有老師的支持絕對沒有現在堅強的我。這份師恩，元鈺會永記在心。

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這次研究可以順利完成，要感謝很多很多協助或是參與我實驗研究的同學們，包含小杰倫、老趙、子豪、聖荃、柳吟、估達、致遠、豆豆…等等好多好多人，要不是你們提供你們的創意思維，這份研究是沒辦法有這些成果，你們才是我這段時間研究的精髓。

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最後，我的生涯剛起步，明年我會離開台灣這塊土地，但我依然會堅持自己的信念，努力不懈。我也會用我的熱忱去堅持下去這份夢想。

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Chapter 1: Introduction

1.1 Research Background

Analogy, which refers to similarity between relationships, is of particular importance because it is the main human cognition affecting human learning, thinking, working, and creative work throughout everybody's whole life. Yet Plato declared the analogy was "the most beautiful bond possible." Umberto Eco ridiculed analogy as "Hermetic semiosis", the cabbalistic obsession and paranoid credulity that uncritically leaps to link everything in the cosmos to everything else. Moreover, both the proportional and the participatory varieties of analogy are inherently visual. It requires perspicacity to see what kinds of adjustments need to be made between uneven cases to achieve a tentative harmony. It also presupposes discernment to discover the relevant likeness in unlike thing (Stafford, 2001).

Throughout the design domain, analogy has been ascribed a key role in the architecture design (Lawson, 2004; Rowe, 1998; Leclercq, 2002). Donald Schön, who was interested in the formulation of problems as the basis for action throughout his career, pointed out how powerful the transfer of concepts from one case to the next and from one field to another can be (Goldschmidt, 1999). Most architects used pencil or charcoal pencil to develop their idea in conceptual design process. The lines they drew are obscure that leads to the possibilities of analogy (Smith, 2005). All most architectural designers have their own notebook. When they impress by something, such as any objects, natural forms, or architectural projects, they will note these things by simple sketch with the pencils and their notebooks. Then, they develop their design and try to observe percept, discriminate, and image by these sketches. Thus, visual experience is the essential to designers to discovery new ideas that depend on the quality and quantity of other types of "references". There are different kinds of reference that support the developing design. For example, in creative and conceptual designing, architects often look to books, magazines, and other collections of images to find forms they can adopt and adapt in designs (Do and Gross, 1995) Studying more high quality architectural projects also a powerful way to lead designers' invention and imagination. Moreover, natural form and biological development provides a possible source to inspire some ideas about the production of diversity during design development (Gero, 2006).

In the age of conventional media, most of analogies could be studied by designers' freehand sketching and scholars deduced these two-dimensional sketching materials to understand the design thinking and design process. However, the appearance of digital media has not only

broken the mode of visual analogy in design, but also raised the controversial issue about the possibilities of analogical thinking happened in other kind medium, except for conventional media. Depend on the merit of the new media, the analogy in architectural design has greatly advanced during recent years. To cite one example, zoomorphic appeared in the nineteenth century and few buildings simulated animals or plants. In twentieth century, the concept of "zoomorphic" became more flourish because of the improvement of technologies and the invention of computers. Genetic algorithms, one new mode of finding the best solution relying on working with computer, have much practical merit because it is modeled on natural processes of evolution. Generative architecture ideally allows environmental parameters to dictate the architectural solution as nature does during ontogeny (Williams, 2003). Definitely, this new issue merits our attention. If scholars are to develop efficient design tools for architects, we must know more about analogy in architectural design than presume it is unchangeable in design.

1.2 Problem and Objective

1.2.1 Research Problem

As was stated above, it could be known that the importance of analogy in the architectural field. Studies of design method and process often identify analogy, metaphor, and visual references as important activities in creative designing. Even tough not all architectural designs use analogy in the conceptual design process, it is undoubtedly that analogy is play an important role in stimulating designers' innovation and exploration. Analogical thinking process is a process that designers stimulate designer's creativities and design ideas by integrating or associating with their individual life experience, the nature of objects, the whole creation on the earth, the physics, or life experience. However, **There is no a complete theory describing how analogical thinking process works in design domain.** When the researchers discuss this issue, they usually cited theories from other areas, such as Gentner's (1983) Structure-Mapping Theory and Holyak and Thagard's (1996) the notions of "System Structure".

Moreover, **when scholars explore designer's analogical thinking, they almost focus on sketching and rarely talked about the possibilities of other medium, such as computer.** Generally, analogical thinking are happened in the conceptual design process, which in the traditional view sometimes also means drafted sketching process. Designers use freehand sketch as its primary mode of development because sketching has the essential "dense, ambiguous, and amorphous" fostering their creative capabilities (Goel, 1995; Do and Gross, 1995). Nevertheless, the development of digital media improves the possibilities and broadens

the representation of architectural design in recent years. Many architects begin their original ideas, develop their conceptual design, and expand their invention with digital tools, but some researches are shown that drafted sketching process could not be replaced due to the computational conception requesting humans though to be precise, rigid, discrete and unambiguous which are well known that is difficult to be happened in the human cognitive. It means that traditional designers and some scholars think that sketching-thinking with pencil-remain is an essential design skill (Herbert 1993; Lawson 2004; Robbins 1994).

However, appearance of computer has created a new ear for the modern society. Definitely, computers have been the primary media to think, record, and communicate with others. More and more people note everything with the machines, not pencils. To the architectural design domain, it has already been proved that the conceptual design process could be happened in only digital media (Hanna and Barber, 2001). In spite of the differences between two kinds of media, the digital media could provide with more various essential, which could not be possessed by the conventional media, such as continuous, continuous pliability, localized focus, fluid, biomorphic—in other words quintessentially analogue(Porada, 1999).

1.2.2 Research Objectives

Until now, there is no definite research method to investigate the process because few scholars in design domain focus on how analogical thinking process works. Moreover, analogical thinking always relates to freehand sketches and rarely connects with other medium. **Therefore, this research attempted to investigate what is common point of analogical thinking in design field. Another question is how design medium affect the analogical thinking process. Therefore, two purposes in this research are shown below.** The main goal of this study is to provide experimental evidence regarding differences and similarities of analogical thinking in conventional media and computer.

1. **The same point of analogical thinking process in design field**
2. **The differences of analogical thinking process in conventional media and computer**

1.3 Research Steps

In order to achieve the objectives, there are three parts consisted in this research. Firstly, the experiments are involved two phases. In the phase one, subjects are asked to generate concepts with conventional media, such as pens or pencils, which the subjects used habitually. When the subjects finish their design assignment, they are asked a brief interview which includes describing their design process and answering some specific questions about their

sketches for the minor data of analysis. In the phase two, the author would like to understand the same thing as the first experiment in a computer-aided way. The unsuitable subjects were eliminated from the phase one of the experiment and the suitable ones proceed the phase two of experiment which also contains the same kind of design assignment. Finally, the author chooses three subjects from six subjects.

After these experiments, the second part of the method is the analysis of the results from the fore experiments. The major analytical source is the visual data from experiments, and the minor data is form the verbal data which are the design processes describing by subjects and the questions that subjects been asked after the experiments. Then, the author uses a coding scheme to analyze the major visual data and minor verbal data. In addition, one pilot experiment would be gone on to confirm the structure of experiments is feasible and reasonable. The final part of the research is analyzing the whole data and addressing three phenomena of analogical thinking in design.

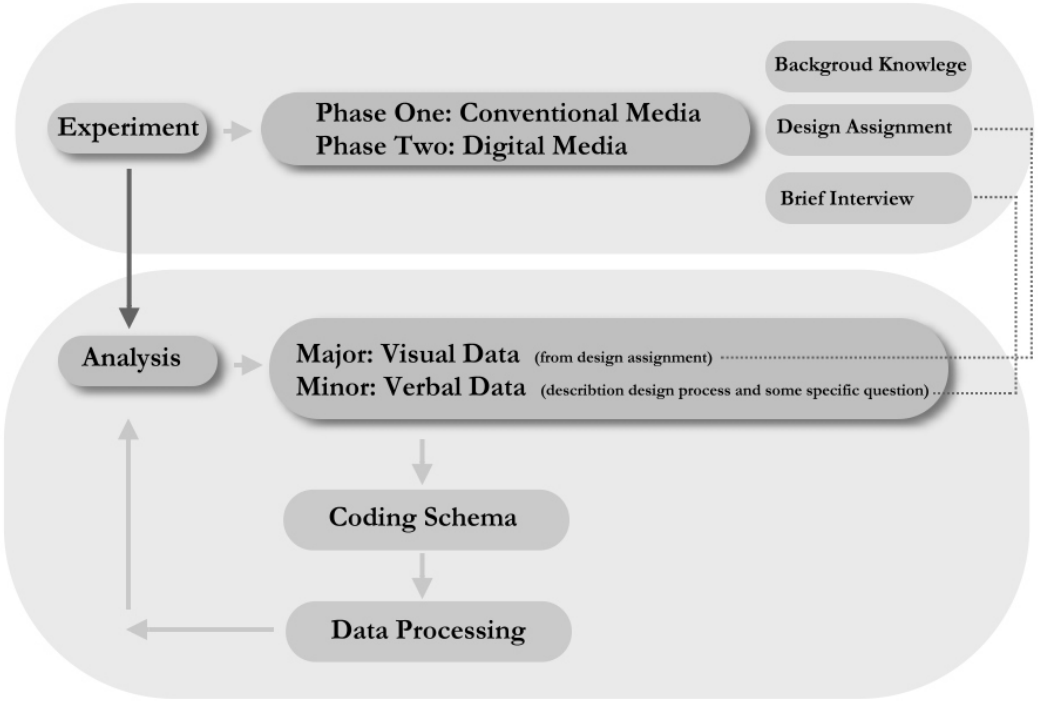


Fig 1.3.1a The Research Structure

This paper structures as five chapters. *First chapter* give the simple image of this paper and research problem and goal. *Second chapter* introduces the research background and formal related work. *Third chapter* plans the entire structure of the experiment. And based on the third chapter the analysis of experimental results is showed in *chapter four*. *Fifth chapter* is conclusion, limitation and future studies.

Chapter 2: Background Review

2.1 Role of sketching in the design process

2.1.1 Design process

Design process has been widely explores in design research domain. Form follows function and function follows form—is a classic expression in design for a long time. Different views about design process have emerged in the last forty years. Alexander (1964) proposed "analysis-synthesis" model for design activities. B. Munari has proposed that design is a process from problem to solving (Liu, 1996). W. Peña and S. Parshall (1987) asserted that design is a process from problem-seeking to problem-solving. DA Schön and G Wiggin (1992) advocated a theoretical model of design thinking "seeing-moving-seeing" and they have the idea that design is a circulation, which means a progress from finding problems with seeing, modifying models with moving, and then observing effects with seeing again. A. Purcell and J. Gero(1999)have proposed that a characteristic of the design process is the use of a number of different types of sketches, and the relatively unstructured and ambiguous sketch occurs early in the process.

Nevertheless, R. Hanna and T. Barber (2001)have proposed that the digital media has transformed the traditional design method of "sketching-to-concept formulation" into "a CAD approach-of thinking-to-concept formulation," which means that designers do not need to use sketching to construct their design when single digital media is used in design process. It demonstrates that the new media has changed the design process. It also means that working in the three dimensional forms demands the architect to more than just a problem solver (Abdelhameed, 2004). The design process has no ideal step-by-step technique; rather, there are many different styles of decision-making, each with individual quirks as well as manifestations of common characteristics (Rowe, 1998). According to Goel(1995), design process has been recognized as involving complex cognitive tasks. The basic activities in design includes exploration of the problem space, creation preliminary solutions, understanding consequences of design decision, and so forth.（Achten and Joosen, 2003）

2.1.2 Sketching

Even though some scholars asserted that the sketching has replaced by single digital media in the design process (shown above), sketching still possesses some important characteristics deserving our attention. Theses characteristics are also helpful to make us know more about

design process, understand how creativities are stimulated by sketching and try to find the same nature happened in the digital media.

Sketching of image has been a part of human cultural production for a very long time. If evidence from hunting gathering societies in any guide, people drew before they built. As a symbol, sketching has a dual and contradictory nature for societies. Sketching is the phenomenal representation of a conceptual practice; moreover, sketching can also provide a code or template that guides the social production of the object it represents. Within architectural practice, sketching as a pure cultural conception and cultural production defines the world free of any institutional, political, or economic constraints (Robbins, 1994).

At the same time, sketches are the designer's principal means of thinking: the origin, nature, and method of obtaining knowledge in architectural design can be explained largely in terms of a few culture-dependent properties of study sketching (Herbert, 1993). Sketching today serves as primary medium for generating, testing, and recording individual architect's own creative and conceptual musing about a design. Sketching is also seen a language because it is used to communicate ideas with others and to instruct other about design, and describe a world of objects through a series of personal and conventional representations. It cannot be described by any grammar because of its level of ambiguity and the multiplicity of ways that it can be seen, cannot be readily described by the use of other sketching in the same way (Robbins, 1994).

In addition, sketching are more than just a convenient way of working out design problems. According to the book "what designers know" by Bryan Lawson (2004), the process of sketching is one of the best ways we know to absorb design ideas. The need to pass an idea from eye to mind and then hand results in a level of understanding not necessarily achieved when simply looking at or even photographing an object or place. Paper and pencil sketches are one form of externalization of mental images, and therefore can inform us about characteristics of these images (Gero, 2001).Architectural designers are taught to use conventional paper and pencil media when developing conceptual designs. Beginning with the simple sketch, the doodle, and the proverbial cocktail napkin diagram, designers develop ideas graphically through the medium of freehand soft line sketching on tracing paper. Sketching activities include finding, adapting and combining new forms with previously learned shapes and structures, for example from precedents, design studio experiences and case studies. Designers sketch to explore design solutions, to record their ideas, or to illustrate them and communicate them with others. The act of sketching is important not only as a vehicle for communication; it actually helps designers see and understand the forms they

work with (Do and Gross., 1995). Architects could not promote their idea without using sketching in it germination or its evaluation. Wile defining, exploring, and redefining a design problem, architects construct, evaluate, and form their design ideas by utilized different type of sketching (Abdelhameed, 2004).

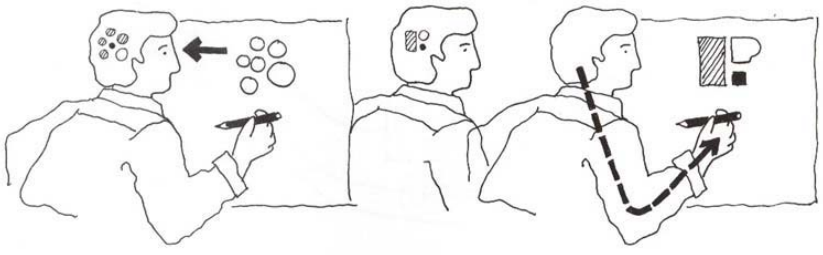


Fig 2.1.2.a Sketching thinking process（Laseau, 2001）

When we understand the importance of the freehand sketching, how it is difficult to be replaced and what the special characters it possessed deserves the attention. Early in the process, designers generate as many ideas as possible. Freehand sketching are integral to this process, raw sketches that can be readily generated, revised, refined, and consolidated in concert with development of the ideas. Sketches serve as a thinking tool for designers (Robbins, 1994; Schön, 1992; Goldschmidt, 1995). Suwa (2001) also presents a view about freehand sketching. He asserts that sketches are used by professionals not just to express ideas but also to generate new ones. Reexamining old sketches, even one's own, can lead to the discovery of new ideas. It is through their reinterpretations that old sketches may be used to generate new ideas. One way is through regrouping parts of a sketch to form new wholes. Goel(1995) indicates three characters about why the symbol system of sketching be correlated with the preliminary stage of design process, which including: firstly, the dense ordering of symbols in the system of sketching gives the tokens a degree of fine-grandness by making every distinction count as a different symbol. This reduction in distance between symbols helps insure that possibilities are not excluded and helps to transform one symbol into another. Secondly, ambiguity of the symbol system of sketching insures that the reference and/ or contents of symbols during the early phases of design are indeterminate. Ambiguity is important because one does not want to crystallize ideas too early and freeze design development (Fig 2.1.2.b). Lastly, the dense ordering of reference or content classes in the symbol system of sketching insures that possibilities are not excludes and helps to transform one idea into another.

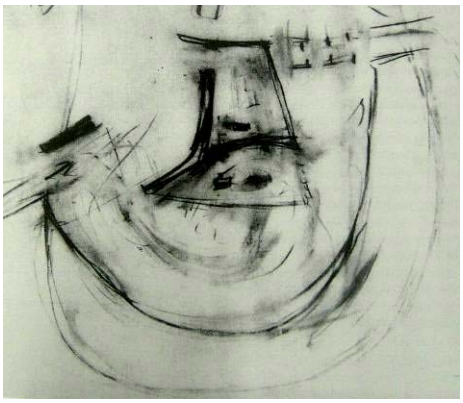


Fig 2.1.2.b Le Corbusier: part of sketch showed the ambiguity (Herbert, 1993)

2.2 Analogy in design

2.2.1 Analogy

Analogy, born of the human desire to achieve union with that which one does not possess, is also a passionate process marked by fluid oscillations. Perceiving the lack of something—whether physical, emotional, spiritual, or intellectual—inspires us to search for an approximation resemblance to fill its place(Stafford, 2001). Analogy is also a particularly useful approach for solving an unfamiliar new problem without adequate or directly applicable knowledge. The idea in the use of analogies in theory construction is to use knowledge from some other domain as a source of new ideas to construct the theory in the target area (Prieditis 1988). The aim of the cognitive activity is “to simulate” the perceived real while elaborating a mental analogy, and to simulate the conceived real while elaborating an analogon idea. In these conditions, the analogy, that appears us in the beginning and to the term of the knowledge, is the means and the end of it at a time. (Morin, 1986)

It is possible to find examples of analogous models in very early stages of human development, since one of the most common strategies for resolving problems is in fact imitation, the reproduction by other means of an external referent, often taken from nature(Pita, 2005). Based on the nature of the knowledge transferred from previous experience to the new problem, the analogical reasoning approach can be classified into two categories: transformational analogy and derivational analogy (Carbonell 1982). Transformational analogy adapts the solutions to the past problems for the new problem. Derivational analogy applies the past problem solving processes or methods to solve the new problem. By analogy, the relations between the new problem and some past experience or knowledge about a particular phenomenon can be found. This experience or knowledge can be placed in the new situation so that the new problem can be better understood or a new plan for solving the problem can be generated (Gero, 1991).

2.2.2 Analogy oriented architecture

Throughout the design literature, analogy has been ascribed a key role in the design of architectural masterpiece (Lawson, 2004; Rowe, 1998; Leclercq, 2002). The reason analogy is important in the context of design has to do with the displays that designers consult. As noted earlier, such displays are extremely diversified in nature and origin, and as we shall presently show, they do not necessarily benefit design as exemplars within the domain in which the designer is working (Goldschmidt, 1995). To support analogy, discovery and invention are presented as an important focus of their work. Discovery brings the power to bear on a problem at a moment in time and the success of discovery in design is greatly dependent on the quality and quantity of the other types of graphic thinking. Invention seeks the basic discovery, the original idea for the project; concept formation converts the discovery into a graphic and verbal statement that can give the basic direction to the full development of the project. The power of a good inventor to invent depends on his ability to see analogies between results and, secondarily, on his ability to see them between devices (Laseau, 2001).

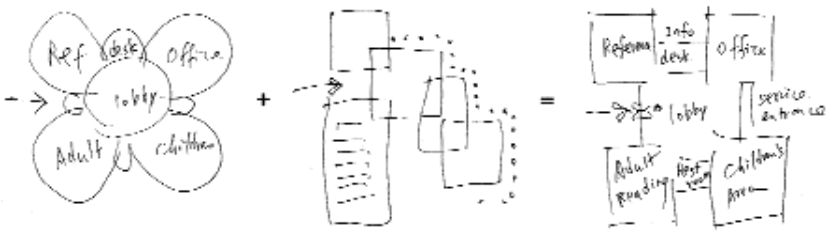


Figure2.2.2.a visual analogical process by sketching (Do and Gross, 1995)

The design literature uses the term" analogy" very loosely, as we use it in everyday life, where it often denotes similarity or resemblance in a general sense (Goldschmidt, 1995). It is a process that designers stimulate their creativities and design ideas by integrating or associating with their individual life experience, the nature of objects, the whole creation on the earth, the physics, or life experience. It means that architects inspired their design ideas by their experience. According to Rowan's opinion (1962), the term "experience" defined that the quality of individual life, and perhaps the survival of human life as a whole, depends on the ability and disposition of human being to think original thoughts, to reshuffle familiar facts into new pattern of meaning, to perceive reality behind illusion, and to engage in daring leaps of the imagination. For example, Tzonis(1992) has dwelt on the use that was made by Le Corbusier of a number of images, which Tzonis refers to as precedents, including a ship, a wine bottle-rack, the savage hut and the Greek temple. Tzonis claims that the forms Le Corbusier invented for Unite Habitation were (Figure2.2.2.b), in part, in analogy to those

images, which Le Corbusier retrieved from memory (Goldschmidt, 1995). Other Examples can be found in the oeuvre of no less than Frank Lloyd Wright, Rem Koolhaas and Gerrit Rietveld- the name only a few. The columns of Wright's Johnson Wax building (Figure2.2.2.c), for instance, would have been shaped by analogy to water lilies. (Leclercq, 2002)

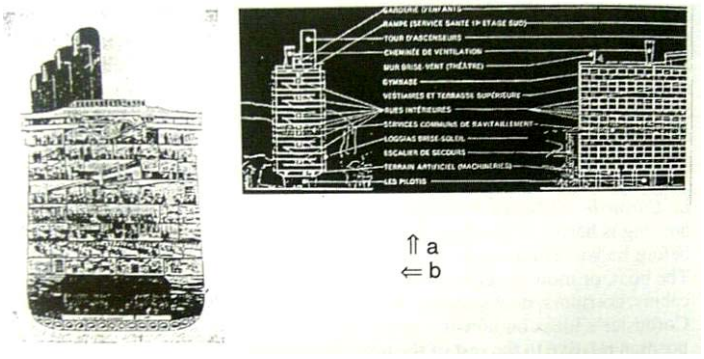


Figure2.2.2.b [a] The Unite Habitation in Marseilles
[b] The Ocean Liner Poster (Goldschmidt, 1995)

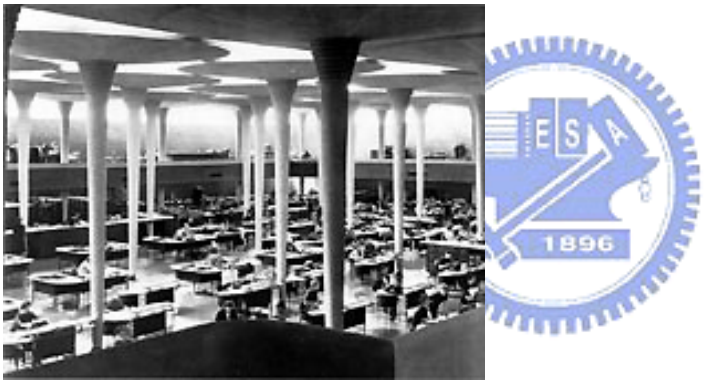


Figure2.2.2.c The columns of Wright's Johnson Wax building

Empirical research on analogy in architectural design has focus primarily on the use of visual analogies (Leclercq and Heylighen, 2002). Of all instances of analogy, designing is most concerned with visual analogy. Sketching gives rise to interactive imagery and enhances analogical reasoning (Goldschmidt, 1995). Graphic design process is assisted by sketching. Most architects used pencil or charcoal pencil to develop their idea in conceptual design process. The lines they drew are obscure that leads to the possibilities of analogy (Smith, 2005). There are two possible ways that the analogy happened in graphic design process. First, designers look for forms that are similar in shape to what they have in mind, and perhaps rough sketches on the sketching board suggest or recall a shell, a rock, or an architectural precedent. Le Corbusier's crab shell roof for Ronchamp would seem to fit this category. Second, designers think of forms that are linked through some concept about the design at hand. For example, the section of Kahn's performing art center at Fort Wayne has the form of

a violin in its case. Here the concept of music and the need for acoustic richness in a concert hall seemed to play a key role in suggesting the building's form. We call these two ways of finding visual references 'shape reminding' and 'conceptual reminding' (Do and Gross, 1995).

In addition, analogy is a powerful problem solving strategy that can help explain new and non-routine problems in terms of familiar ones. The production of an unlimited number of unexpected solutions that are significantly different from earlier designs is a characteristic of non-routine design. Design problems are described as major examples of non-routine problems (Gero and Maher 1993). Thinking in terms of analogy involves the transfer of prior knowledge from a familiar situation (named the source), to a situation that should be elucidated (named the target). Structure-Mapping Theory supports the view that an analogy can be characterized as the application of a system of major structural relations from a source, to the problem to be solved (Gentner 1983).

2.2.3 The classification of analogy

When we understand the importance of analogy in design domain, we should know how to definite analogies and where analogies come from. Different views are showed by several scholars.

Firstly, Ricoeur (1994) reported five levels of analogy: the analogy of proportion and equal relations, form, function, organization or structure, the free analogy, or poetical. The five levels are established on the whole state of language. In the poetics, analogy in the sense of "proportion" is at the root of the fourth class of metaphor. Proportion relates two quantities of the same kind in direct relation of one to the other. The structure is the arrangement of parts in a piece of writing. Other levels, such as form or function, are the elements of language. In addition, the "property" does not be included in the five levels of analogy since the property belongs to the sphere of things, not of a word. But the limitation does not happen in design field.

1. Proportion: equal relationship between A and B
2. Form: a way of writing
3. Function: some special purpose of a word or a writing
4. Organization or Structure: the arrangement of parts of literature or poem.
5. Free analogy or poetical: imaginative metaphor and showing deep feeling

Secondly, William Gordon(1968) has defined four types of analogy: symbolic, direct, personal, and fantasy.

1. Symbolic: it is a comparison between general qualities of the two objects, such as the Latin cross and the plans of many churches.
2. Direct: it compare parallel facts or operation. For instance, the house is designed to have the same cooling characteristics as a tree shades.
3. Personal: the designer identifies himself directly with the elements of the problems. Assuming that the prime consideration for this house is warmth and comfort on the winter days without large use of nonrenewable resource, the designer might imagine him to be the house. To make himself comfortable, he might lie close to the ground below the ridge so the cold wind can pass over his head.
4. Fantasy: it uses a description of an ideal condition desired as a source for ideas. In the case of our recreational house, the designer might fantasize about a house that opens itself up when the client arrives on the weekend and automatically close up when the client leaves. It could symbolize a tulip that opens and closes.

Moreover, Paul Laseau(2001) also defined these “references” in details(Figure2.2.3.a). He showed that the analogies are easily recognized in our everyday invention. The possible models from which to draw analogies can be classified by categories as physical, organic, or cultural, and the subcategories include:

1. Structural: Referring to shape or relationship.
2. Mechanical: The way something operates
3. Control: Maintaining a condition
4. Plant: Goal orientation and differentiation
5. Animal: Behavior
6. Man: imagination and choice
7. Society: interaction, competition, organization
8. Symbolic: conventions, references, suggestions

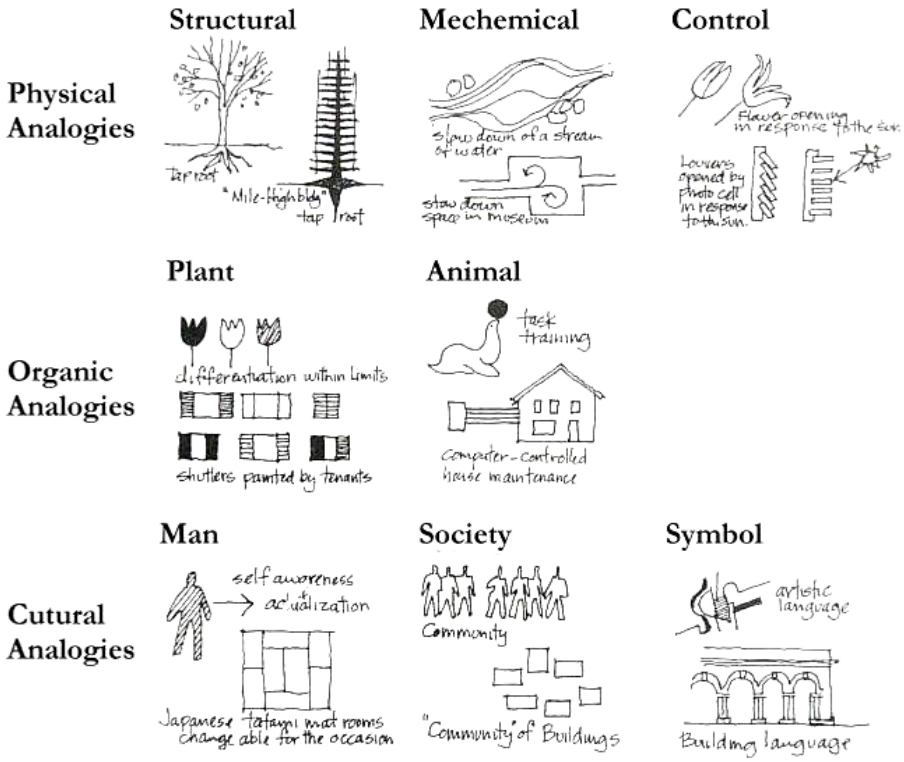


Figure2.2.3a The sources of analogies (Laseau, 2001)

In addition, among the all kinds of sources of analogies, organic analogy, which is also called the biologic analogy, is the most important type of visual analogy. Biology is a recursive source of architectural inspiration due to the tight relationship between form and function, the natural balance of forces and the corresponding geometric solutions found in living beings. Roughly, one can classify historical analogies between architecture and biology into two main categories. The first tries to mimic biological forms and the second biological processes (Couceiro, 2005).It is very common to see life forms represented in architecture. We have all seen buildings with biomorphic allusions to plants, animals or even anthropomorphic allusions. Furthermore, architects and designers like Frank Lloyd Wright have referred to organic architectures not only from the shape but also from the functioning point of view (Couceiro, 2005). Accounts of creative architectural design often mention natural and artificial objects as sources of architectural form. For example, Le Corbusier wrote, “the shell of a crab picked up on Long Island in 1946 is lying on my sketching board. It will become the roof of the chapel”. Le Corbusier also urged young architects to study and draw from nature. Similarly, Wright stated that the form of his Unitarian meeting house in Madison, Wisconsin derived from the form of hands clasped in prayer (Do and Gross, 1995).

Figure 2.2.3.b:.
[a] Le Corbusier's Ronchamp - a crab shell;
[b] Wright's Unitarian meeting house - hands clasped in prayer. (Do and Gross, 1995)

2.2.4 The Construction of Analogy

To instantiate the utilities of analogical thinking to designing, the author shows some theories of analogy from other fields. Firstly, K. Holyak and P. Thagard(1996) proposed the notions of "system structure" given with the help of explaining analogical thinking. It fundamentally involves the simultaneous satisfaction of the constraints of similitude, structure and purpose. The analogy functions through a construction of relation between the object source and the goal object in establishing relations of different level of similitude. When people think analogically, people do much more than just compare two analogs on the basic of obvious similarities between their elements. Similarity at a more general level emerges as the results of applying the constraints of structure and purpose. These constraints apply at all stages in analogy use: selection, mapping, evaluation, and learning. After a source analogy has been selected, that maybe by active retrieval from memory or by some references point it out, mapping can guide the construction of similarities between the source and target. Once two situations have been mapped and the source has been used to generate inferences about the target, one might suppose that the job is done- the process is evaluation. The final stage is learning more general schemes as a consequence of solving problems by analogy.

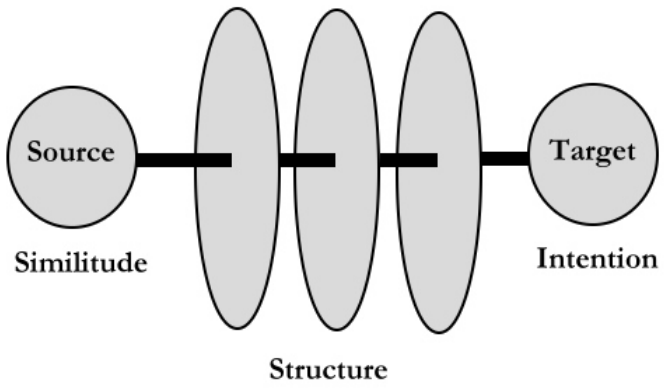


Figure2.2.4a System Structure

Secondly, Gentner(1983) asserted that an analogy can be categorized into surface analogy and deep (structural) analogy. Surface analogies relate to easily accessible or superficial concepts of object properties. Structural analogies, on the other hand, involve a system of higher order relations that are based on deep properties of a familiar situation. The structure-mapping theory distinguishes three levels of complexity in analogical thinking, each of which is tied to an increasingly abstract form of explicit knowledge: attribute mapping(based on attributes of objects), relational mapping(based on higher-order relations between relations), and system mapping(based on higher-order relations between relations).The interpretation rules are characterized as implicit rules for mapping knowledge about a base domain into a target domain. Gentner's structure mapping theory paves the ways for a theory of transfer of configurationally relations from a display(base, or source) to a task at hand(target). Configurational qualities equate syntax which stands for structure, whereas issues of subject matter equal semantics, or object attributes and features in Gentner's model. The notion of configurational transfer is important because it is relevant to our efforts to provide the designer with assorts displays in the form of visual databases. Besides, Novick(1988) has shown that for experts, problem solving makes positive use of analogical transfer when the features shared by the base problem and the target problem are structural. In contrast, when the base and target share surface features (object attributes) transfer is more like when the problem solvers are novices, and it is often negative transfer.

Moreover, Casakin (2004) reported that the main processes of analogical reasoning consist of: (i) identification and retrieval; (ii) mapping and transference. An analogy can be established between two different domains, each of which embrace dissimilar knowledge, but with a common shared correlation based on similar structural aspects. This type of analogy is known as "between-domain", where the source and the target problem belong to different and distant domains. In cases in which source and target are embedded in the same or very close domain, the analogy is called "within-domain" (Casakin , 2004). In addition, Ilse M. Verstijnen(2001) addressed the third kind analogical domain " within domain" that is the source and target stem from the same domain. Therefore, analogy has different aspects and three kinds of domains, and where the sources of domains come from.

2.3 Digital media in Architecture

2.3.1 Conventional media and Digital media

The development of media has several periods. In ancient time, almost architects expressed their design process with written record (Hweitt, 1985). Designers only showed their abstract concepts of visual design by two-dimensional sketchings before the Renaissance era when the

representation of architecture design was still limited (Goldschmidt, 1999). Even though the scale models have appeared in Ancient Egypt, classic Greece, and Imperial Rome, they almost were used to religious activities (Smith, 2004). The most important attribution of Renaissance architects was that they started to use a vast number of small-scale models in the design process to display their concepts. This new way of representation could make the result of design more accurate (Millon, 1994).

By the beginning of the twenty century, the limitation of traditional architectural form was broken by a few architects, but these innovation buildings were only built by imagination. However, the way we engage in the design process has been changed the appearance of new technology when computer appeared. The traditional media as sketch concretes designer's ideas in the way of sketching plans, elevations, sections, and perspectives on a sheet of paper, but the computer media serves as an integrated design tool provides 3D modeling, animation, audio/video representation, and even the virtual reality and the co-operation in internet environment on design. Such character of this new media not only make the complexity of design form possible, but also effectively speed the design process, lower the budget, and improve the communication with each other (Lin, 2003). It not only breaks the traditional design methods but also increases the possibilities that exist within the design experience: digital media has the capacity to improve design cognition, intuition, and creativity (Hanna and Barber, 2001). It is possible that the traditional architectural elements, forms, and the spaces are redefined by digital media because it offers designers a better way to think (Madrazo, 1999).The impact of computer media on design is enormous and powerful.

2.3.2 Comparisons between two media

In 1963, Ivan E. Sutherland, who is the pioneer of using digital media, proposed that the plan of developing the sketchpad, the digital medium of line sketching. After that a large number of researches focus on computer-aided design. Three important characters of the digital performance include: First, digital information was transformed into the eyeable algorithm. Secondly, users-defined parameters are display by hierarchical menu or input. Lastly, computer-aided designs use machine, such as printers, the appearance of images, and computer-aided manufacturing. Digital media restructure the architectural representation that leads to infinite possibilities (Mitchell, 1998; Ho, 2006).

However, some scholars question the probability that the conventional media could be replaced by the digital media. For example, Goel(1995) argues that the cognitive computational conception of the world requires our thought processes to be precise, rigid, discrete and unambiguous; yet there are dense, ambiguous, and amorphous symbol systems,

like sketching, painting, and poetry, found in the arts and much of everyday discourse that have an important, nontrivial place in cognition. He also maintains that while on occasion our thoughts do conform to the current computational theory of mind, they often are—indeed must be-vague, fluid, ambiguous, and amorphous. He argues that if cognitive science takes the classical computational story seriously, it must deny or ignore these processes, or at least relegate them to the realm of the nonmetal (Goel, 1995). In addition, some research on the functions of sketching in architecture (e.g. Herbert 1993; Lawson 2004; Robbins 1994) remind us that though digital media is used for making and editing mechanical working sketching and for producing renderings and animations for clients, sketching is still the medium of choice for creative design and design development. Despite software that helps designers produce cleaner and more precisely drafted sketchings, few designers feel computer tools actually help in developing designs. It may be that CAD software is too structured for conceptual design thinking, which uses freehand sketching as its primary mode of development. sketching-thinking with pencil-remains is an essential design skill (Do, 1995). Due to the essential of sketching, many researches have been done to improve computational design system for sketching and sketching. For instances, Wellner(1993) provide a system called DigitalDesk(Figure 2.3.2.a) to enhance sketching and sketching behavior. The Electronic Cocktail Napkin(Figure 2.3.2.b) developed by Gross(1996) is am experimental computer-based environment for sketching and diagramming in conceptual stage of design. Lim (2003) made an experiment comparing differences and similarities between the digital media, the Electronic Cocktail Napkin, and traditional freehand-sketching. He had a conclusion that there are few differences between the two interfaces and using computer environment could make the sketching strokes transform into the concrete digital three-dimensional images. Thus, digital use this media that could gain more visual feedbacks that includes not only ambiguous sketching lines, but also specific three-dimensional images.

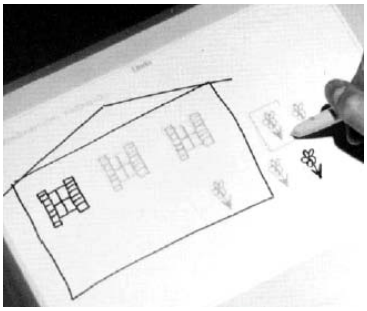


Figure2.3.2.a the DigitalDesk

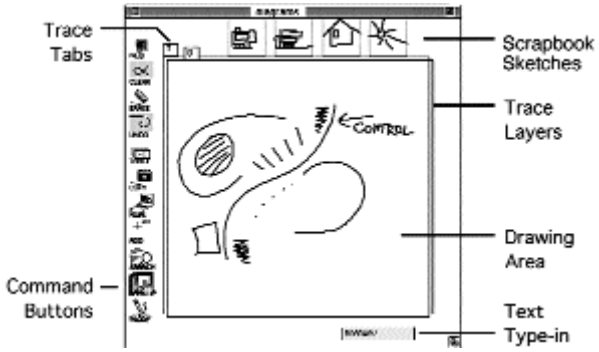


Figure2.3.2.b the Electronic Cocktail Napkin working screen

Apart from attention to how we simulate the freehand sketching in the digital media, broadening the potential of the digital media is the important issue. Architecture that is always very attentive to the technological innovations remains for the meantime conservative in its whole, and seems to be influenced more in its form by new construction technologies and materials. Their use produces transparencies, disappearances, apparitions and new space dialectics: interior-outsides, skin-structure, etc (Porada, 1999). A number of applications have shown that graphics CAD systems can be operated by lay users to make an effective contribution to architecture. An important advantage of the computation design systems is that they can provide users with access to tutorial, engineering and cost-evaluation procedures. This information may help users to create design alternatives with realistic cost and performance attributes (Aish, 1986). Due to these advantages of digital tool, some scholars believe that the drafted sketching process could be replaced by only digital media. R. Hanna and T. Barber (2001) proves that using digital media as the only design tool can be addressed. When experimenters were asked to use digital tools only, they modified their design approach. Instead of using the conventional approach of sketching⇒concept formulation, experimenters shifted to new approach—a approach of the digital media—of thinking⇒concept formulation. Further empirical research is needed to assess the impact of this shift on the quality of design solutions. Figure2.3.2.c is show an attempt by the experimenter to use digital media as a tool to enhance the creation process of design composition. The experimenter has created a ‘penetrating' design composition by breaking the rigidity of the linear grid with a diagonal, non-orthogonal mass.

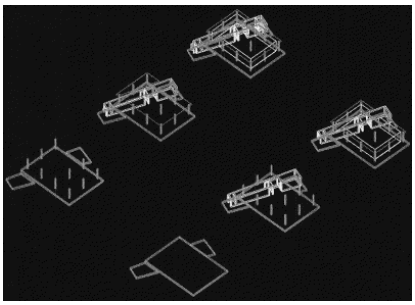


Figure2.3.2.c Using the digital media as the only tool in the conceptual design process

2.3.3 Three Dimensional Representation

The three-dimensional application is one of the manifestations of the computer media in digital design. Although the sketching conventions are economical to use, the problem with a two-dimensional symbolic system is that perceptual ambiguity may occur when multiple two-dimensional views are used to communicate more complex three-dimensional objects. It is acknowledged that three-dimensional graphics, such as perspective views, can be used as an effective output system, but it is difficult to see how users can directly generate or manipulate three-dimensional geometry via such computer-generated views (Aish, 1986). The three-dimensional model is on an equal level as a structural model, physical model, materialization model, and so forth. It also possesses some special characteristics differ from other design media. For example, making architecture become more three dimensional in design exploration and in representation is one of the most important characteristics of the 3D modeling. This transition to three dimensions makes the processes of visual design thinking more related to digital media (Abdelhameed, 2004). Designers can simulate designs by using many different angles and scales, when they are no longer restricted by the two-dimensional grid.

In addition, Sorte (1975) demonstrated that different two-dimensional and three dimensional graphic, photographic and modelling techniques used to represent typical buildings may not evoke the same responses from subjects as did the buildings in reality. In particular, he found that plan sketchings were an unsatisfactory presentation method, while simple three-dimensional models were more effective. One of the factors which, it is suggested, contributes to the success of physical modelling presentation methods is the facility which such a modelling system provides for the user to acquire an unambiguous perception of the size and shape of exterior forms and interior spaces by allowing the user to vary his eye and viewpoints. The user also moves around (and possibly through) the model and is, therefore, able to achieve compatibility between visual and positional cues which will also occur in the perception of the real building. Three-dimensional modelling systems provide a design environment which is more realistic and therefore is likely to evoke responses which are more similar to the responses to real buildings (Aish, 1986).

Not only realistic, three dimensional applications possess some other special characters that other kinds of media do not have. Henri Achten and Gijs Joosen(2004) defined several distinct characteristics of the three-dimensional model of digital design process including:

1. Continuous modeling

During the traditional design process, the designer usually produces a lot of sketches and models, which involve many resketching, tracing, and modeling; however, the three-dimensional model has a potentially longer life-span which does not require continuous reconstruction.

2. Continuous pliability

The technique of three-dimensional modeling allows for a gradual development and refinement of a shape without the need to delete an old shape and create a new one. It becomes easier to consider the shape as a preliminary one which is under constant revision, rather than as a fixed shape.

3. Localized focus

The level of detail can be adjusted in the places under consideration by means of refinement of the underlying NURBS-equation. This implies that design change occur locally while the rest of the model updates the changes that are made.

4. Postponed decision

Combined with the characteristics of localize focus, designing becomes a constant process of gradually refining parts of the design; at the same time, the three-dimensional model has to be translated to a built-able solution. Such transformation usually leads to a loss of versatility. It means that the decision of to “collapse” a surface has be postponed and also showed that three-dimensional model has to seen as temporary.

Chapter 3: Experiment

In order to achieve the objectives, there are three parts consisted in this research. Firstly, the experiments are involved two phases. In the phase one, subjects are asked to generate concepts with conventional media, such as pens or pencils, which the subjects used habitually. When the subjects finish their design assignment, they are asked a brief interview which includes describing their design process and answering some specific questions about their sketches for the minor data of analysis. In the phase two, the author would like to understand the same thing as the first experiment in a computer-aided way. The unsuitable subjects were eliminated from the phase one of the experiment and the suitable ones proceed the phase two of experiment which also contains the same kind of design assignment. Finally, the author chooses three subjects from five subjects.

After these experiments, the second part of the method is the analysis of the results from the fore experiments. The major analytical source is the visual data from experiments, and the minor data is form the verbal data which are the design processes describing by subjects and the questions that subjects been asked after the experiments. Then, the author uses a coding scheme to analyze the major visual data and minor verbal data. In addition, one pilot experiment would be gone on to confirm the structure of experiments is feasible and reasonable. The final part of the research is analyzing the data and addressing three phenomena of analogical thinking in design.

Fig 3.1a Structure of Experiment

3.1. The experimental clarification

In this section, the author describes the details about how to design the experiment and how to conduct the experiment. They are involved the subjects choosing, two phases of experiment, the design topic of experiment, design tools, the recorded methods and the limitation of the experiment.

3.1.1. Choosing Subjects

The object of research tries to understand analogical thinking process in design domain and explore how designers transfer of concepts from one field to another. Accomplishing the process should possess abilities which are abundant creativities and expertise in architecture design. Therefore, the author selects sex expert designers who have more than five years of design-based education. All of them are proficient at conventional media and computer simultaneously. They use one or more computer applications frequently when they generate their designs.

However, every designer has different design method and thinking. Even though these subjects have professional design experience, it does not mean that all of them could design with analogical thinking. The short warm-up experiment could not prove effectively that the chosen subjects are suitable for designing with analogical thinking. In order to make sure that the experimental results are worth discussing, six subjects participate in the phase one of experiment and then the author measure the experimental results based on the following basic analogy theories (Novick,1988; Genter, 1983; Holyak and Thagard,1996; Goldschmidt; 1995). If any subject's design does not achieve any one of the two theories, he or she is unable to go on the next phase.

1. Analogical thinking is a process form source to target.
2. The positive use of analogical transfer is that the features shared by the source and target are structural. In contrast, when the source and target analogy shares only objects attributes transfer, it is often negative transfer.

Finally, three of these subjects cannot accomplish the objects. One subject indicates that he could not think with analogical transfer to design. Experimental results of two other subjects show only objects attributes in their design.

3.1.2. Two phases of experiment

When the researchers discuss the analogical transfer, most of them mention the relationship between analogy and sketching. The author tries to comprehend the analogy in design domain deeply and understand the analogical thinking process in different media. However, every subject has different design thinking and method. The only way to judge the comparison between analogical thinking using conventional media and computer fairly is that let the subjects participate in two experiments using different media. Thus, the experiment has two phases. The phase one is a design assignment using conventional media and the phase two is

the other design assignment using computer with similar topic. Two phases have an interval of one month.

3.1.3. Brief interview

After every phase of design assignment, a brief interview would help the author understand the design process accurately. The analogical thinking is too complicated process to understand only by visual data. When the subjects remain memory, they are requested to describe the design process, and then some specific questions are asked by the authors. The brief interview is about fifteen to twenty minutes.

3.1.4. Experimental topic

Every analogical thinking process involves source and target (Genter, 1983; Holyak and ThaGard,1996; Goldschmidt; 1995). Thinking in terms of analogy involves the transfer of prior knowledge from a familiar situation (named the source), to a situation that should be elucidated (named the target) (Gentner 1983; Novick 1988). The identification and retrieval of a similarity between potential relations in the target, and known relations in the source enables to understand the new situation on the basis of a familiar situation.In design domain, the source means that something inspires the design idea and the target signifies the design purpose. This experiment is the short time design assignment and subjects must finish their conceptual design within restricted time. Also, the source and target are not the main research goal in the study. In order to achieving the experimental purpose in limited time, the design ideas and the design purpose are bounded by particular resource and one topic.

The sources of analogy are various, such as structural, mechanical, plant, animal, society, etc, but the organic analogy is one of the most widely discussed issue in design domain (Couceiro, 2005; Do and Cross, 1995; Gero, 2006). Therefore, the author selects two organisms that the subjects maybe know but not really familiar with, and offer them the reference materials to them to build their knowledge background.

In addition, the design purposes cannot choose traditional topics that are too easy to design, but complex topics also are not a good selection to quick designs. Therefore, novel topics have simple function that it is easy to handle and has much space to be developed. Finally, the author decide the first design topic in the phase one is “a roadside stall design which inspired by the concept of the jellyfish.” The second design topic on the phase two is “transient living space which inspired by the concept of the sponge.”

3.1.5. Building background knowledge

In order to avoid the surface analogy (Gentner, 1983), the author offers a material to build the subject's background knowledge before the beginning of every design assignment. The material containing text and graphics have explicit introduction about two design sources "jellyfish" and "sponge". All kinds of knowledge about the sources are listed to improve efficiency of obtaining information from the material. Subjects have ten minutes to read the material before generating their design. When they start developing their design, they still can skim the material at any time they need.

3.1.6. Experimental tools

The subjects are requested to use their habitual tools in the two phases of experiment that make them generate their concept as usual. In phase one, the author asks the subjects to prepare the conventional tools that they use habitually. In the phase two, it also does not limit what kinds of applications the subjects use. The author arranges for all applications that the subjects need, such as 3Ds max, Maya, Sketch up and FormZ. Besides, the author prepares the AMD Turion 64 Mobile notebook with 15.4 inch monitor, keyboard and mouse.

3.1.7. Experimental time and recorded methods

Because the subjects generate their conceptual design in recorded circumstance, the experimental time could not be too long. Subjects generating conceptual design in experiment phase one is about forty minuets. The pilot experiment shows that when designer generating their design with computer is more time consuming than conventional media, so the design assignment in the phase two is about one hour. If subjects think the time is not enough to complete their design concept, ten minutes could be prolonged. In addition, the whole processes are recorded by video. For the unease of getting visual data, the author takes a photo with digital camera per minute.

Fig 3.1.7.a the experimental environment and recorded methods

3.1.8. Limitation

Analogy has the various types, different levels, and diverse resources, but this study is only aimed at organic analogy as the experimental topic. Because the author focuses on the analogical thinking process, much variability would disturb the objectives of the research. Therefore, the author has to choose one kinds of analogical transfer that must be the limitation of this study. On the other hand, it is difficult to find expert designers who proficient at conventional media and computer simultaneously, but too few experimental data are unconvincing. Ultimately, the author chooses experimental result of five subjects to be the analytical data of the study.

3.2. Experimental scheme

This section discusses two parts of the research including hypothesis, two phases of the experimental design assignments.

3.2.1. The phase one: design with the conventional media

The Phase one of the experiment is about the process that designers generate their design by analogical thinking while they use conventional media in the concept generation stage. The objective in the phase is to comprehend the process analogical thinking accurately and regard this results in this phases as the foundation of studying the analogical thinking in digital media.

1. Subject: six architectural designers who have perfect ability of generating concepts, using conventional media and proficient at one or more digital media. They all have been educated with more than 5 years of architectural design.
2. Topic: the new type of roadside stalls which inspired by the concept of the jellyfish. The topic has simple functions that it is easy to handle and has much space to be designed.
3. Tools: the conventional tools that the subjects use to generate conceptual design, such as papers and pens.
4. Process: subjects were asked to generate one or more conceptual design.
5. Time: The sum is about one hour. Before the subject start to generate, the author described the demand of experiment to the subjects and also let them to read the related materials and think for ten minutes. Then, the subjects could generate their design for forty minutes. If they think the forty minutes are not enough to complete their design concept, ten minutes could be prolonged. After the concept generation part, the author would ask the subjects to describe their design process and answer some questions about twenty minutes.
6. Recording Process: during the experiment, the subjects are recorded by video among all

time. And the author used digital camera to catch some visual images.

7. Interview: After the experiment, the subjects are some specific questions about their design for the minor data of analysis. This process would be recorded by the voice recording and the video.

After one phase of the experiment of, the author has known the analogical thinking process of designer while using conventional media generating concepts. After the experiment in the traditional way, the experiment in computer-aided way in the same degree is that the author mainly discuss. Therefore, there comes the phase two of the experiment.

3.2.2. The phase two: design with the digital media

This phase is about the analogical process that designers generate their conceptual design while using computer media. The objective is to know if the analogical thinking of generating concepts could be happened in the computer-aided aspect.

1. Subject: three architectural designers proceed the experiment two because three unsuitable subjects are eliminated (the reasons are shown the next passage).
2. Topic: transient living space which inspired by the concept of the sponge. The topic has simple functions that it is easy to handle and has much space to be designed.
3. Tools: Hardware (AMD Turion 64 Mobile notebook, 15.4 inch monitor, keyboard and mouse), Software (computer applications that the subjects use habitually to design, such as 3Ds Max, Maya and Sketch Up, etc.)
4. Process: the same as the phase one.
5. Time: the sum is about one hour and twenty minutes. The time of subjects generating their design extends to one hour. Other parts are the same as the phase one.
6. Recording Process: the same as the phase one.
7. Interview: the same as the phase one.

3.3. The summary of the experimental process

The passage is a discussion about the experimental process and results. The recording data (visual data) is the main source and the brief interview (verbal data) is the minor data. The author uses the two kinds of data to describe the design processes of three subjects. The key point of this passage focuses on subjects' analogical thinking process, not the design results.

In addition, because every subject carries out two phases of experiment results, three subjects have six experimental results and processes. Therefore, this section is divided into two parts included phase one and phase two. Before describing the experimental processes, there is a brief description of the background of the three subjects. The full detailed data, such the whole recording data or texts of brief interview, are given in Appendix.

Subjects A

Architectural design-based education: six years
Experiment of computer aided design: five years
Choice of conventional media: pen and ink
Choice of computer application: 3Ds Max
(Currently he uses computer as main design tool and conventional media as supporting tool.)

Subjects B

Architectural design-based education: seven years
Experiment of computer aided design: five years
Choice of conventional media: pencil
Choice of computer application: 3Ds Max
(Now he uses computer as only design tool, but sometimes he use freehand sketching to stimulate design ideas.)

Subjects C

Architectural design-based education: six years
Experiment of computer aided design: two years
Choice of conventional media: pen and ink
Choice of computer application: Sketch Up
(He need to use both conventional media and computer application to design.)

3.3.1. The results of experiment phase one: using conventional media

Subject A

Subject A spends fifty minutes to complete phase one of experiment. At the beginning, he reads the source material and searches some keywords relating to space, such as flocking together, illuminated, transparent, water jet and moving in reverse direction, and so on. Then he begins to select some interesting images and learns the forms. He tries to find some special forms or structures from the jellyfish; therefore, he firstly draws jellyfish, and then responds to the design topic" roadside stall."

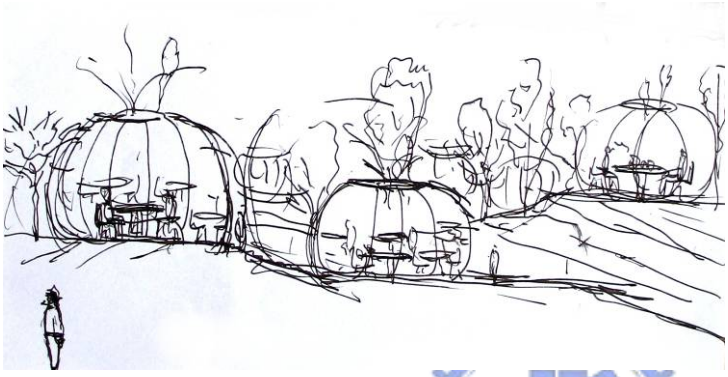


Fig 3.3.1.a Subject A's design result

The process of imitating and sketching the form of jellyfish takes about 23 minutes. Firstly, he sketches simple patterns of jellyfish (Fig 3.3.1.b (a)). Later, he draws the umbrella structure of traditional stalls, or is the style of traditional roadside stalls (Fig 3.3.1.b (b)). Finally, he tries to connect sources and target. He puts the simple sketches of jellyfish and the sketches of roadside stalls together (Fig 3.3.1.b (c)), and thinks how to build a relationship between them. He draws, thinks, ponders, and sometimes goes back to read the source material. In the process, he finds new keywords or new meaning and writes them down, such as clusters symbolizing combination, eight meridional canals, water signifying transparency, and so on.

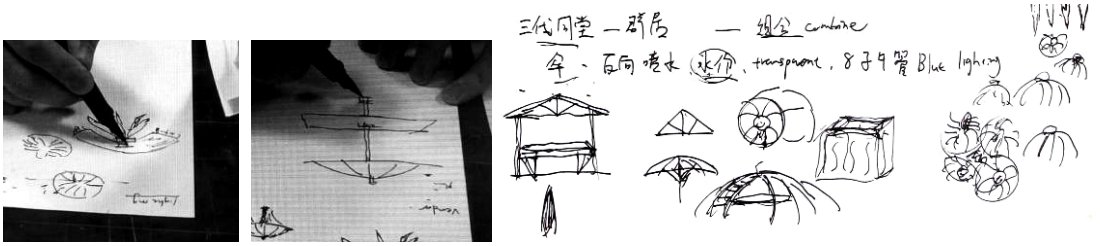


Fig 3.3.1.b (a) Imitating the form of jellyfish

(b) sketching the umbrella structure of traditional stalls

(c) putting the simple sketches of jellyfish and the sketches of roadside stalls together

"When I generate my design, I could not always draw and draw. Sometimes I need to stop sketching and thinks which sketch has the potential to develop. There is a transitional period from simple imitation to design. Moreover, the previous sketching also help me to has a flash of inspiration for my design."

Then, Subject A chooses jellyfish tentacles and jellyfish's character "flocking together" to sketch, and tries to use the two key points to stimulate his thought. When he draws one sketch (Fig 3.3.1.b (c)), he makes sure that this one is his conceptual diagram. Then he draws a simple elevation to show the concept of his design (Fig 3.3.1.b (c)). Finally, he uses another paper to draw details, functions, or structures about his design.

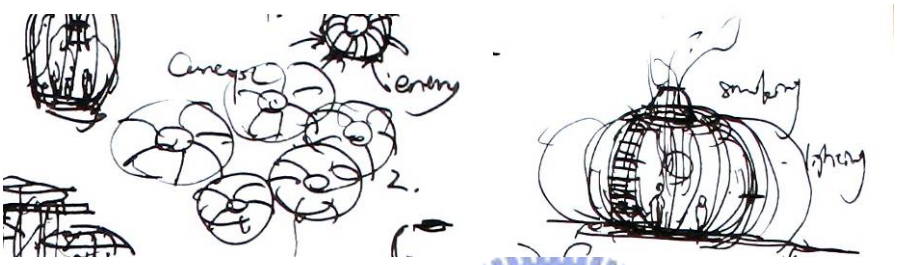


Fig 3.3.1.c (a) conceptual diaram
(b) Elevation of final conceptual design

"I think that the first step of analogical thinking oriented design should be search, and then draw something which you see in the source material. The intuitive process can make designer quickly understand its structure, and it is helpful to the later exploration and development. In fact, the form would be transformed. At the beginning, the first sketch is really like a jellyfish, but designer may find some important points in the first sketch, and applies them to the next sketch or transfers them to other new thing. The process of sketching many diagrams could be accumulated a power to provoke designer's creativities."

As far as the analogical ideas are concerned, Subject A searches some key words at same time, but every diagram are discussed only one key words. After sketching many diagrams, he starts to consider how to integrate these ideas. The definite transfers of analogical ideas would be presented in final conceptual design. For example, at the beginning, he catches the some key words, such as cluster, light, water jet and moving in reverse direction, tentacles , and so further. The final design represents the large or small group of stalls, LED light source, the line-shaped skeleton framing, and so on.

Subject B

Subject B takes 45 minutes to complete phase one. Like Subject A, he spends almost time on the mapping stage and he decides his final conceptual design at 33 minutes. At the beginning, subject B reads source material and write some keywords quickly, including zooplankton meaning can morphing, flocking together symbolizing combination, containing water meaning inflated. In addition, because he thinks intuitively that the jellyfish is a "round" animal, so the basic form of his every sketch is round.

Fig 3.3.1.d Subject B's design result

He begins to think how to integrate these ideas and how to make them become part of a design. He draws umbrella structure of traditional stalls, and parallel relationships of roadside stalls (Fig 3.3.1.e). Then he starts to think how combine the source "jellyfish" and the design target" roadside stall" together.

"When I think about how to connect jellyfish with roadside stalls, I draw a basic form of roadside stalls to understand what its characters are. Then I look at the previous diagrams describing jellyfish, go back to draw the form of stalls, and look at the jellyfish diagrams again. The process makes me know how to combine them together. For example, I find that stalls have the character of horizontal arrangement, so I try to draw many circles to see whether these circles are arranged to has some direction(Fig 3.3.1.e Right), but I feel it is very difficult."

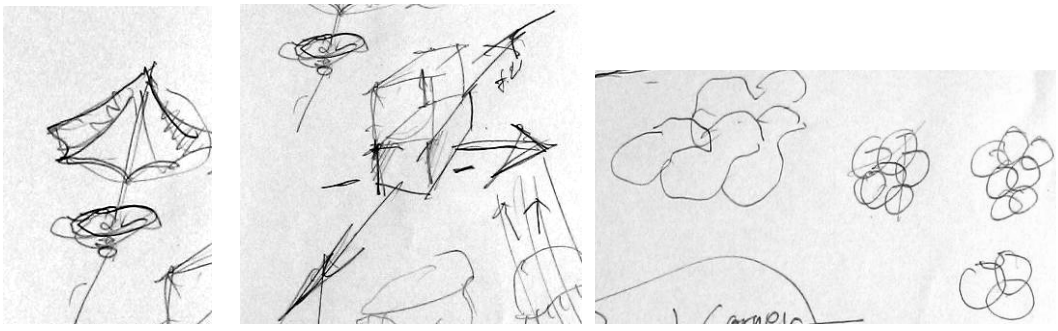


Fig 3.3.1.e (Left) Umbrella structure
(Middle) parallel relationships of roadside stalls
(Right) arrange some circles

Later, subject B finds that it is difficult to manipulate his design idea. He stops sketching and write down some key words promptly. In this time, he finds a new key word “reverse” that stimulate the developmental stages of jellyfish (the form of jellyfish reverses in different stages). He begins to manipulate the possibilities of “reverse”; however, reversing something with two-dimensional angle is restricted. He could not continue to test his ideas and finally abounds this idea.

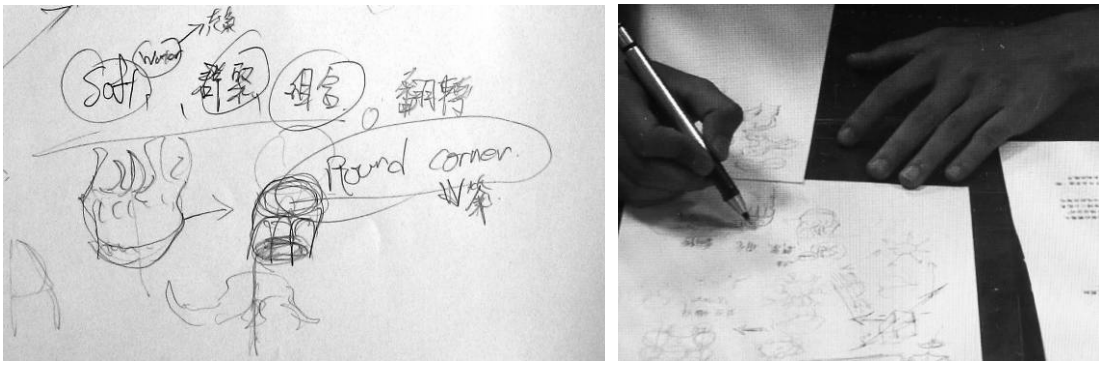


Fig 3.3.1.e (Left) Subject B finds the new key word “reverse”
(Right) sketching process

“In the process, I test the possibilities of flocking together. When I search the new idea” reverse”, my thought is really confused. Because there are too many interesting ideas, I do not know how to combine them with one design or how to present them with one angle. Therefore, in the difficult circumstance, I continue to draw many diagrams. When I draw one diagram, my intuition tells me this is my conceptual diagram.”

The final concept is decided after repeating the process of writing keywords, sketching jellyfish diagrams, and roadside stalls diagram. Then he draws some detailed structure, functions about his design with another paper.

As far as the analogical ideas are concerned, subject B also reads the source material and searches some interesting key words. However, because there are many analogical ideas, he could not integrate them into one design concept at once. Therefore, he repeats many times in the process of writing keywords, sketching jellyfish diagrams, and roadside stalls diagram. His definite analogical transfers also represent in the final stage, including the form, structure, inflated, and flocking together. In particular, subject B applies the concept of jellyfish’s flexible body to his stalls design that the form of stalls could be changed and spreaded on the surface by changing tangent lines.

Subject C

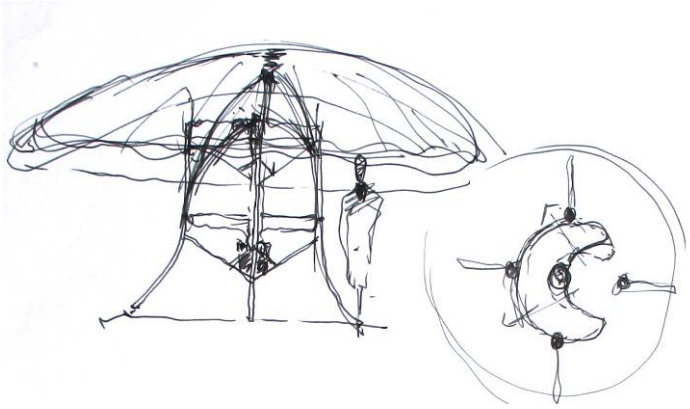


Fig 3.3.1.f Subject C ‘s design result

Subject C spends 46 minutes to complete the phase one of experiment. At firstly, he writes down some keywords, such as containing 95% water, transparent, three layers of jellyfish’ body, slender tentacles, cnidoblast(a type of cell as a means for jellyfish catch prey and defend themselves from predators), and luminous body. At the same time, subject C writes down some keywords to express the characters of roadside stalls, such as not fixed, cluster, luminous lighting for attracting people, and so on. Then he links the keywords of jellyfish with the characters of roadside stalls (Fig 3.3.1. g Left). In the mapping process, he draws one simple sketch of jellyfish (Fig 3.3.1. g Right).

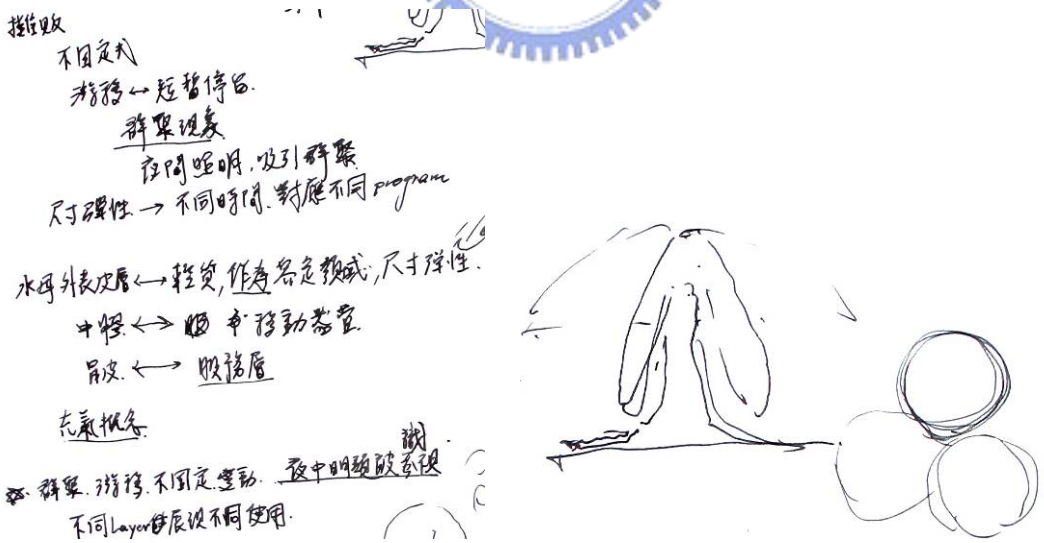


Fig 3.3.1.g (Left) Subject C writes down some keywords and build relationships between source and target
(Right) One simple sketch of jellyfish

After the mapping process with keywords, he confirms some relationships of functions between source and target. At 17 minute, he begins to use some sketches to visualize these

relationships (Fig 3.3.1. h Middle). At this stage, he tries to combine the relationship with the image of jellyfish in his mind. He draws four diagrams to describe his thinking.

"I think the jellyfish is a light-weight and transparent animal. I consider how to connect this image with my concept. Then I think maybe I can use inflatable membrane to symbolize the movement of contracting muscles and then releasing the contraction, the feeling of light-weight, and the transparent appearance. Moreover, I transfer jellyfish's tentacles as a skeleton, so I start to draw my conceptual draft. After finishing the draft, I begin to consider more realistic parts, like how to inflate the stall, how the skeleton framing works, the scale relationship between the stall and the person, etc."

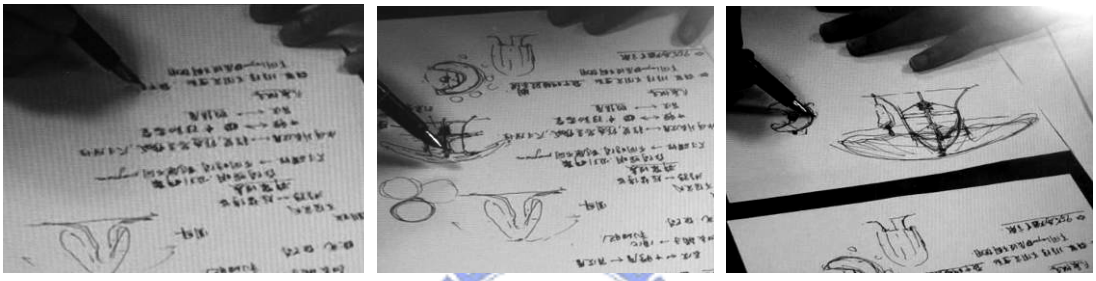


Fig 3.3.1.h (Left) Subject C connects the relationship between source and target
(Middle) Subject C draws several drafts to visualize the relationship
(Right) sketching main sketch to show his design

At the final stage, subject C builds almost design ideas and he starts to draw the final conceptual diagram. He draws one main sketch to show his design (Fig 3.3.1. h Right). Then he draws several minor sketches to describe detail about design function (Fig 3.3.1.i Left), present how to link every unit into clusters, and show the three levels of service function symbolizing the three layers of jellyfish's body (Fig 3.3.1.i Right). The analogical ideas that he uses is the same as the keywords which he search at the beginning.

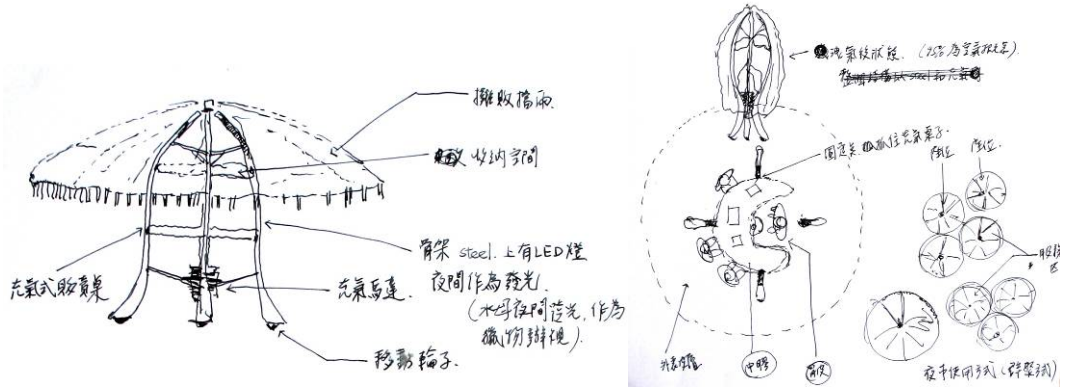


Fig 3.3.1.i (Left) design functions
(Right) three layers of services, cluster, and inflation

"It is easy for me to generate design ideas with keywords because what I write can directly transfer a draft. The lines of draft are rough and ambiguous, but they are full of designer's thought."

3.3.2. The results of experiment phase two: using computer

Subject A

Subject A takes 59 minutes to complete the phase two of experiment. After reading the source material, he chooses one of sponge's tubular structures "Leuconoid" to be his main design idea. Secondly, he also use the concept of the water folwing which water enter spongocoel through incurrent pore and flow out through osculum transfer into aerial currents of the living space. Then he generates his design with 3Ds Max.

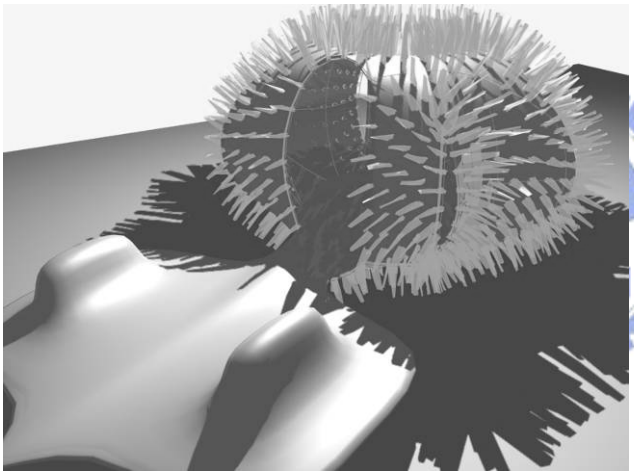


Fig 3.3.2.a Subject A's design result

As the beginning, subject A imitates the sharp of sponge. He established an arc-shaped object, and hollows out the object. In order to edit different level, he multiple several copies of the same object,

Subject A edits every object to generate the pores, the skin, skeleton framing, etc. He uses one model to complete his final conceptual design. Finally, he establishes an animation (Fig 3.3.2 b). This animation symbolizes the sponge' abilities "morphing" and "reproduction."

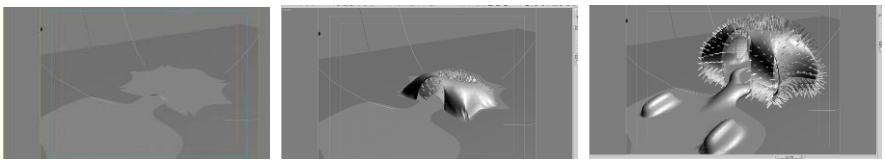


Fig 3.3.2.b The animation

As far as the analogical ideas are concerned, at first he just applies one or two analogical ideas to his design. When he generates his design in different stages, he adds new analogical ideas into his design. For example, when he edits the surface of object and excavates many holes (Fig 3.3.2 b Left), he put the analogical transfer “tubular structures” into the design. When he builds the skeleton framing, he stimulate the special structure of sponges’ skeleton (spicule) (Fig 3.3.2 b Right). All analogical ideas happen in different stage of design process. Every move the designer do sometimes means that they put new transfers into their design.

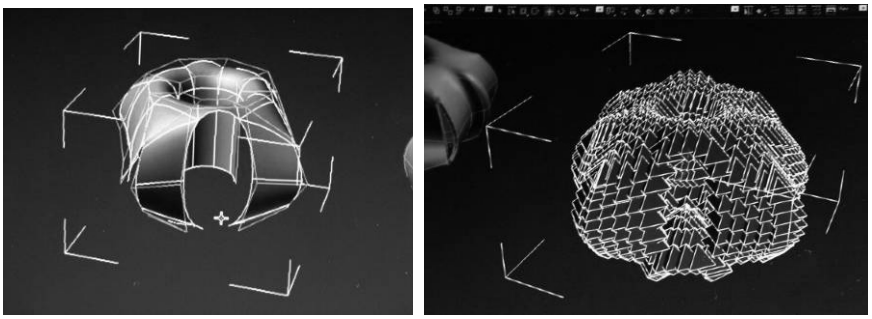


Fig 3.3.2.b (Left) excavating many holes
(Right) skeleton framing

In addition, Subject A has several evaluating situation, which means he spends more time on testing different parameters or functions. He tries to find the most suitable form or functions. This situation occurred in several design stages. The time is long or short.

“When designers generate their design with conventional media, what they draw affect their next step of their design. It is a step by step process that the final design result is decided by the previous study. However, computer allows the designer to explore numerous creative solutions to problems. When designers adjust a parameter or input a command, they can find novel points and the design may become a new look that they cannot imagine before it. At the same time, it also means more time consuming because designers must study with different parameter and find the suitable result they want. ”

Subject B

Subject B spends 60 minutes to complete phase two of experiment. At firstly, he quickly reads the source material, searches some keywords and writes them down in Power Point. The two main analogical ideas that he apply to develop his design is the ability of reproduction and the tubular structures.

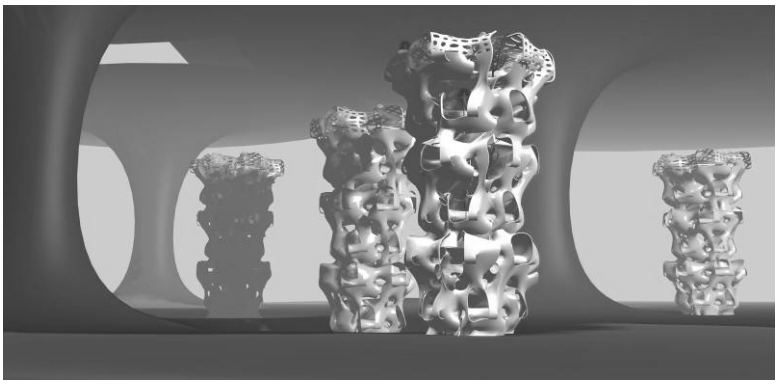


Fig 3.3.2.c Subject B's design result

Then he uses 3 Ds Max software to generate his design. At the beginning, he use simple cube to establish the unit and he modify the cube to make it become free-form and possess many holes. He multiples the unit and arrange them in circle. Then he links every unit and makes them have some common paths. He establishes a relationship of mutual links between every unit. Later, he multiple the group of units and stacked the new group below the original group. After that he links the every unit and two group again He repeated this process many times until his design like a hollow barrel.

"I produce a unit and copy many units. I think that the relationship like Single-cell reproduction. The source material discusses "Sponge, also called Protozoa, is more than the most primitive cells in the animals, the most simple of a group. Therefore, I apply the analogical ideas and transfer it to my design. Not only the concept of Single-cell reproduction, but also the Structure of sponge are my analogical ideas. The sponge has spongocoel which the hollow body, so my design concept is a hollow building. Many pores appear in my design that likes the relationship of porous sponge."

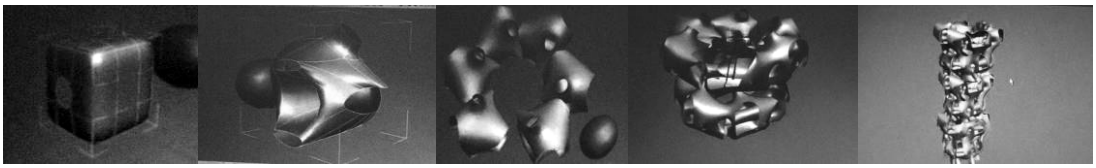


Fig 3.3.2.d Subject B's design process

Then, Subject A tries to generate the opening above the building. In this process, he spends much time on evaluating. He tests five or six parameters (Fig 3.3.2.e) and wants to find the best one. After complete one building, he multiplies several copies to transform the concept of flocking together. He takes a lot of time to establish a base and render to some conceptual images.

"I think it is a multiple family dwelling. I use the concept of sponge's tubular structures to connect every unit and offer a new concept of housing. Every unit or whole group reflects the tubular structures. The opening comes from inside to outside or from outside to inside. There is no floor and it like the growth of organization."

Fig 3.3.2.e Evaluation: he spend much time on testing different parameters

At the design process, Subject B begins from one or two simple analogical ideas and then adds some new ideas at different stages of the design process.

Subject C

Subject C spends 52 minutes to complete phase two of experiment. When he reads the source material , he uses Word to record the keywords, which sponge's tubular structure "Asconoid", velocity of current affecting the shape of sponge and movement of sponge , and osculum flowing out water

"When I find that the sponge could swing by Water flows, I imagine that housing needs the light and ventilation. Asconoid is the simplest structure of sponge and at the top of asconoid has a opining. I think it could be transformed to the top of housing has light and the air can outflow from the top opening."

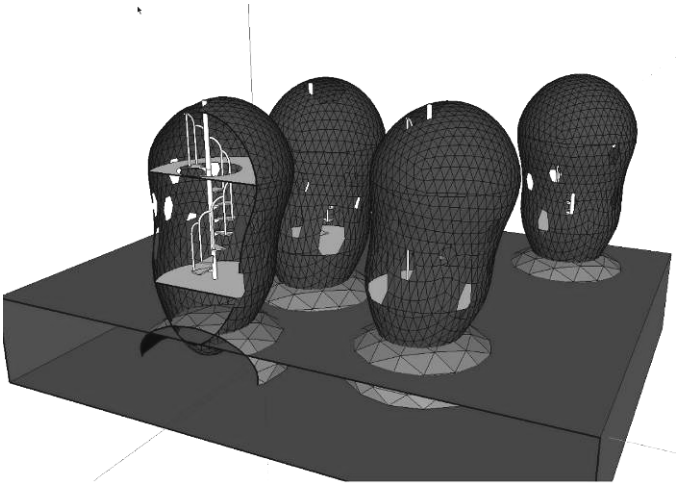


Fig 3.3.2.f Subject C's design result

Then he uses his habitual application Sketch Up to generate his design concept. He spends much time on trying to generate the form in his mind, but it does not work. It is difficult to generate free-form organic surfaces by Sketch Up, so he use the application 3Ds Max to build the form which he imagines in mind. However, he is not familiar with 3Ds Max. Thus, after completing to build the form, he imports his model into Sketch Up and continues his design.

"I am not sure that it is restricted or not to generate my design with Sketch Up. In fact, because of the limitation of this software, it has already decided what my design looks like. I know 3Ds Max could help me to design something that I really want, but I am not good at handling 3Ds Max. Moreover, the limited time forces me to reflect my design to more direct analogical relationship."

Then he starts to design other parts, including the metaphor of sponge's Osculum and incurrent pore, the movement affected by time or seasons, and other spatial functions, such as staircase or floor. He not only put the analogical ideas which he captures at the beginning in his design but also considers problems of architectural functions and space. Then he tries to connect the analogical ideas with his architectural functions.

"I think the relationship between current velocity and sponge swing by Water flow could transfer to the movement of building affecting by the different time or different season. The building has a main pole. The building would be rotated or tilted by the main pole. The top opening is moved by different time. For example, the midday sun is very hot, so the building tiles to one side to keep the sun off. Because the temperature and light are changed by diverse time, the building could move to the suitable angle. Therefore, I reflect every analogical ideas I gain at the beginning."

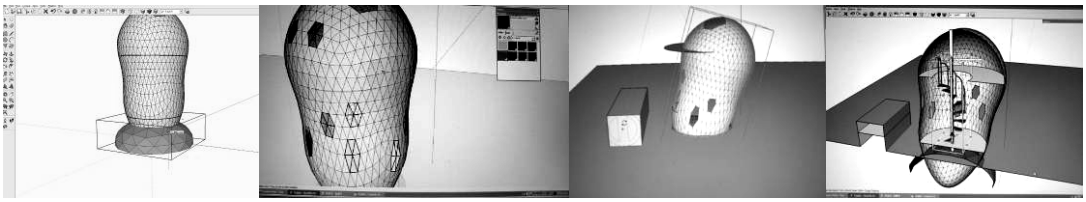


Fig 3.3.2.g Subject C's design process

Finally, subject C manipulates the relationship of color and scale. In addition, Subject C multiples many copies at the base that symbolizes the flocking relationship of sponge. As far as the analogical ideas are concerned, Subject C capture four or five analogical ideas as the direction of design development at firstly. He chooses one idea to start to develop his design and then he adds different idea at every phase of design process.

Chapter 4: Results and Analysis

The chapter is showed the experimental results and analyzes the data. After these experiments are completed, the second part of the method was the analysis of the results from those experiments. The final part of the research is analyzing the whole data and addressing three phenomena of analogical thinking in design.

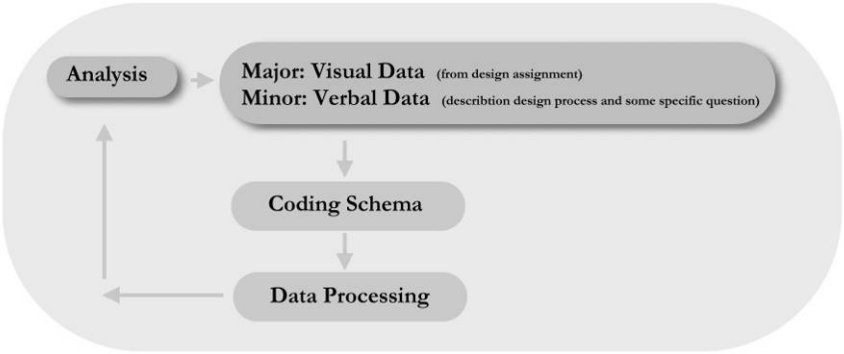


Fig 4.1a Structure of Analysis

The author needs to find the suitable investigating method to analyze whole data. Until now, there is no definite research method to investigate the process because few scholars in design domain focus on how analogical thinking process works. Nevertheless, the author thinks that designer's analogical thinking is still one type of design thinking processes; therefore, the common method for researching the nature of design thinking is applied by the research. Hanna and Barber (2001)proposes that the studies attempts to investigate the design process by recording the designer's behavior and his or her spoken thoughts using several techniques, one of which is the protocol analysis. Introduced by Newell and Simon(1972), and adopted by many investigators, protocol analysis involves setting up quasi-laboratory experiments to record the behaviour of the designer using video-tape (Akin and Lin, 1994), audio-tape (Goldschmidt, 1991), sketches on paper, etc. The objective of studies like Akin and Lin's is to understand the intuitive process in design, using concepts and tools from cognitive psychology, and predict how architects design. Schuck(1973) also asserts that the visual data should analyzed by the method of protocol coding system. Thus, the author integrates two kinds of analogical theories in to the coding scheme to analyze the major visual data and minor verbal data. A conceptual sketch of the entire design process in one phase of experiment is regarded as a section and then each section would be encoded. After coded, each encoded data of sections are put together to integrate and compare with two phases of experiments through several directions.

4.1 The coding scheme

4.1.1 Acquiring analytic data

The major analytical data of this research is the visual data recorded from the experiment phase one and two, and the minor aided data is the brief interview which is asked after the design assignment. This is the research dealing with visual process. The reason why the author chooses visual process for the main analytical data is that it is a tough task to ask designer to generate concepts with computer. So if the designer is still asked to think aloud while doing this tough task, the author believes that the result of the experiment will be disturbed. For this reason, the author decides to use visual data as the main analytical data. Besides, for the unease of getting visual data, the author takes a photo with digital camera per minute. And the total process of experiment is recorded by video in order to prove the total process of visual data.

Additionally, some absent aspects would exist for the only concerning about visual data as analytical source. For example, the analogical thinking is a complex process. Some important processes are happened in subjects' mind, such as what kind of design resource they choose, and how they evaluate the resources. It is difficult to discovery some important thinking with only visual data; therefore, the author decides to use verbal data to aid visual data. The verbal data is from description of the design process by the subjects and some specific questions asked by author after the design assignment phase.

4.1.2 Segmentation

There are huge visual data which collect the six sections from two phase experiments of three subjects, but deleting any part of these data would make the whole analogical thinking process be not complete. The author tries to abridge the visual data by segmenting one section on several paragraphs. The definition of segments in this study is based the shift of subject's intention, of the contents of their thoughts, or of their actions (Suwa, Gero etal. 2000). It also means the design moves that are the basic coherent operation detectable in designing. In present study, a design move is defined as an act of reasoning which presents a coherent proposition pertaining to an entity that is being design (Goldschmidt, 1991). Therefore, the author distributes the section into several moves. For example, the subject C in experiment phase one write down the keywords and then connect the function of the street roadside stall with these keywords. Even though the subject's actions in both moves are writing something, segments in this instance should be coded into two parts.

4.1.3 The coding system

Most analogy theories have been developed primary under linguistic paradigms. There is no specific analogical theory to designing. The author applies some important theories originated from other fields to analyze the rough data.

The author integrates two kinds of theories into one coding scheme (TABLE 4.1.3 b) to analyze the major visual data and minor verbal data. The author focuses on analogical thinking process and the types of analogical ideas. The analogical thinking in design field is a complicated process that designers may transfer several analogical ideas from sources to target, but these ideas do not occur in independent analogical thinking process. Most of them are happened in the same process but in different stage probably. The author tries to investigate the relationship between the idea occurrence and the stages. Thus, the author adopts two theories that come from the background review, which include the four stages in analogical thinking (Holyak and Thagard, 1996) and the five levels of analogies in design field (Ricoeur, 1994).

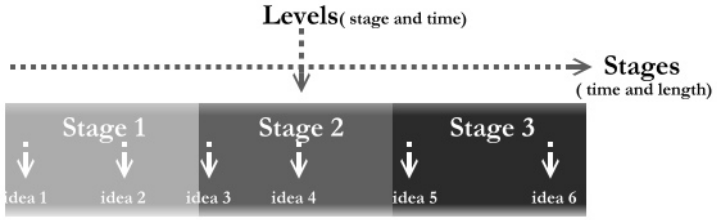


Fig 4.1.3.a Relationship between levels and stages

Firstly, Holyak and Thagard (1996) propose that there are four stages in all analogical thinking included selection, mapping, evaluation and learning. It is the only theory that describes the process of analogical theory. The author uses their opinion to judge the designer's analogical thinking. However, it is found that after the designers specify their analogical ideas to conceptual design, they still spent more time to draw more sketches which describe the detailed functions, structure, activating route and so on. It is a process that is representation of detailed ideas and images held in designer's mind. The author deduces the process call the representation and adds it being a last stage behind the learning. This stage in computer media means that when designers finish their conceptual design, they start to do something to support their design, such as rendering, making an animation, or building the base.

Secondly, there are various kinds of discussing the types of analogy, such as methods of analogy, depths of analogy, the levels of analogy, types of source and so on. In the research, the author mainly tries to know what kinds of spatial relationships of the analogical ideas.

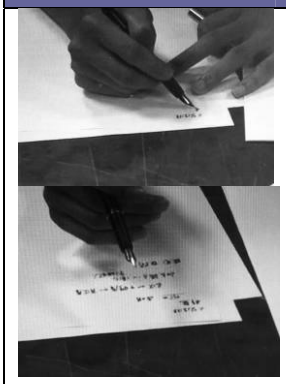
Ricoeur (1994) reported five levels of analogy included the analogy of proportion and equal relations, form, function, organization or structure, the free analogy, or poetical. Even though the theory is based on linguistics and semantics, the levels which the scholars mentions relates the spatial relationships in architecture. The author thinks that this classification not only clarifies effectively the subjects' various kinds of analogy in their design but also support make the author know what levels of analogies happen in different stage and what the sequence of the analogies. The author offers new spatial definition of these levels. However, among the five levels of analogies, the level "proportion" is rare used in architectural field. It more often appear on the field of mathematics due to ratio among numbers in a set (Stafford, 2001). Designers rarely consider exactly relationship of numbers between analogical source and target, and they often use "property transfer". Designers concern about the property of their design and transform some property from other fields, such as light, color, characters or special behaviors, but it is not contained in five levels; therefore, the author decides to delete the level "proportion" and add the new level "property" to the coding system. The five stages and five levels are defined to accurate meaning. Table 4.3.2 shows the coding scheme and definition. In addition, the free analogies in linguistic filed almost possess poetical meaning; however, free analogy (poetical analogy) is difficult to definite in design domain. Therefore, the author removes the free analogy from the coding scheme.

	Coding	**Definition**
Stages		Holyak and Thagard(1996) and the Author's Deduction
S	Selection	Choosing the sources to transfer
M	Mapping	Connecting the sources and target
E	Evaluation	Evaluating two or more decisions and selecting one of them
L	Learning	Confirming and sketching the final concept design
R	Representation	Describe or improve the design details
Levels		Ricoeur(1994) and the Author's Deduction
P	Property	Transferring the quality or characteristic
F	From	Transferring the appearance or shape from source
Fu	Function	Transferring the spatial function
Str	Structure	Transferring structural relationship

Table 4.1.3.b The coding scheme of Analogical thinking

Then, the whole visual data and verbal data are structured by tables. One section is divided into several parts of one table by different moves. Table 4.1.3.c is the instance of one part included the main visual data, time, clarification and the coding scheme. The left area of Table 4.1.3.c is one or more key images of one move which the author adopts from the video recording data. But the analogical thinking process is too complicated to comprehend by only images, the clarification would support the visual data to be coded. Then, the author gives a short explanation about the move and offers other additional interpretations which come from the subjects' brief interview or summary the analogical levels. The right area is the coding system that involves the five stage and five levels. Every move is classified to proper level. If any analogical idea happens in the move, the author would classify it to the suitable level.

The author defines the time of the analogical idea by the visualizing the definite analogy. For example, in the phase one, Subject C associates the three level of jellyfish body with the different spatial functions of a stall in the second move from the five minute to twelve minutes, but he does not specify this analogical idea on his sketch until the last move. Therefore, this analogy is counted in the last move.

<table>
<tr><td></td><td>Time</td><td colspan="5"></td></tr>
<tr><td rowspan="4"> 
(One or more visual data in one move)</td><td>Search for key words from the source material.

(The clarification that the author explain the move of the visual data)</td><td>S</td><td>M</td><td>E</td><td>L</td><td>R</td></tr>
<tr><td rowspan="3">He writes down 95% water, transparent, three layers of jellyfish body, slender tentacle, nematocyst, and illuminated.

(Additional interpretation about the analogical levels or the subject's verbal data)</td><td></td><td>■</td><td></td><td></td><td></td></tr>
<tr><td colspan="5">(Classify the move to proper level)</td></tr>
<tr><td>P</td><td>F</td><td>Fu</td><td>Str</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="2">(If any analogical idea happens in the move, the author would classify it to the suitable level)</td></tr>
</table>

Table 4.1.3.c One part of the section: it is the instance of whole process of one section. All sections of the experimental processes are given in the appendix.

4.1.4 The coding results

This passage contains coding results of whole experiments. The author uses the coding scheme to analyze the major visual data in the sketching process of three subjects. The relation between coding result of three subjects and time can be produced as a figure. Fig 4.1.4 a is a model about how the author constructs one coding result included time, moves, stages and the level of analogy. All of them are integrated into a complete figure that aids to search any analogical information. Firstly, every move is encoded by the fit stage, and then all moves are combined to a complete process which is composed of full stages. The information of analogical stages, such as the length, sequence, and so on, could be gotten by the figure. Moreover, the several white circles lying below the figure reveal what time, what stage and what level the analogical idea happen.

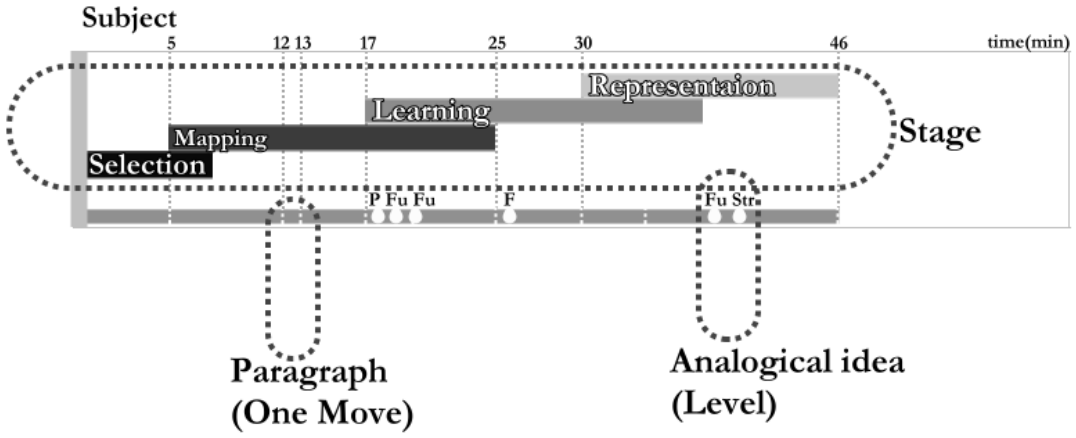


Fig 4.1.4 a The model of coding result

Figure 4.1.4 b represent the whole coding result between coding result and time of three subjects who generate concepts with conventional and computer media. From the representation of these three figures, we can clearly see the shifting times and amounts of analogical behavior of three subjects. According to the convenience of pens and papers, subjects in phase one can generate a rough sketch in a short time. According to the immediate visualized feedback of computer, subjects in phase two would generate a more concrete sketch in a longer time. Generally, every stage consists of one or more moves. Five to eleven analogical ideas happen in one section. To analyze the data effectively, the author separate the coding result into three directions included analyzing by stages, levels, and relationship between stages and levels. Then, the author will apply the general ideas gaining to support the further analysis in the next passage.

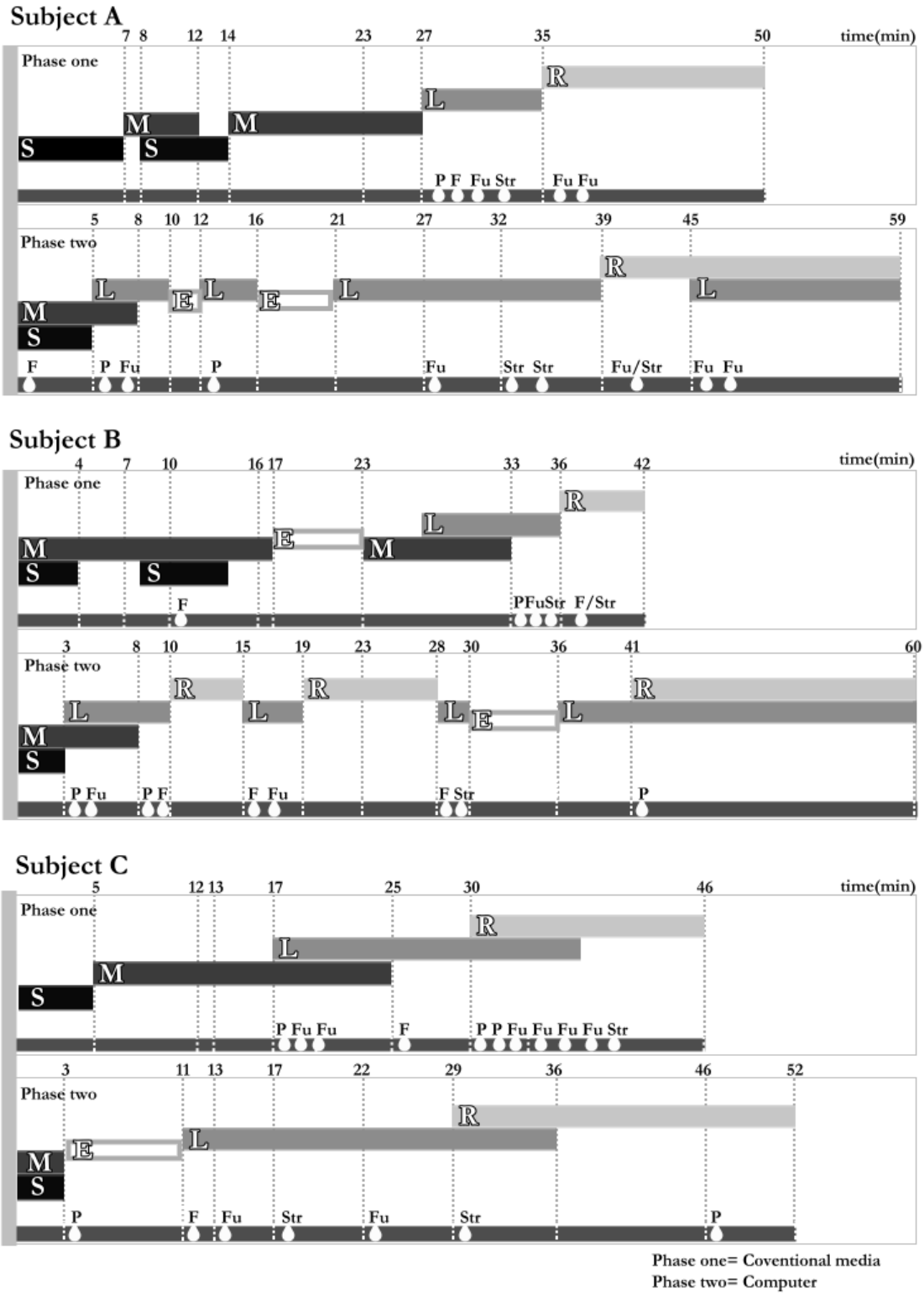


Fig 4.1.4 b The coding results

4.2 Three phenomena of analogical thinking

In this passage, the author integrates coding results, visual and verbal data to analyze three phenomena of analogical thinking.

4.2.1 Phenomenon One:

Designers search some key words or meaningful pictures that contain spatial metaphor to be their analogical sources. Then they transfer the sources to equal architectural relationship.

The central parts of understanding analogical thinking are how the designers pick their analogical sources and how they connect the sources with design target. The author discoveries a general rule of designers' analogical decision. It is that designers search and decide some spatial keywords or images, such as color, light, function, structure and so on. They write down these keywords or draw some sketches to support their thinking. In the two phases of experiment, the author offer source materials to build subjects' background that is detailed knowledge about the source in the materials, such as this animal's body structure, life habit, appearance, and so further. The author discoveries that when all subjects read the material, they search some key words relating spatiality or some images which has a spatial metaphor. In the phase one(conventional media), for example, all subjects choose some characters of jellyfish hinting some spatial meaning, such as illuminated, umbrella structure, flocking together, body containing 95 % water, and so on. They put these interesting sources in their minds or penciled down on paper.

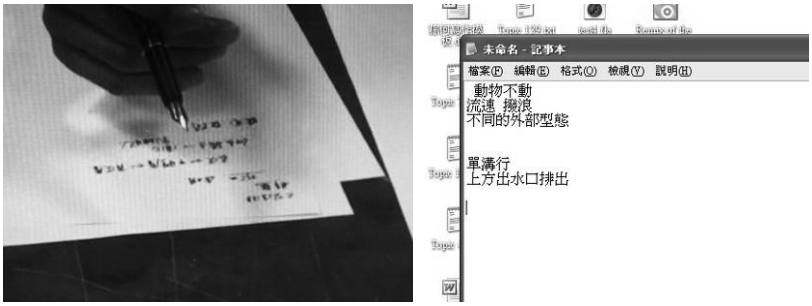


Fig 4.2.1 a designers write down the keywords

In the phase two (computer), all subjects choose one image about three kinds of sponge's tubular structure (Fig 4.2.1 b), because the image is like one architectural section, simple but full of spatial meaning.

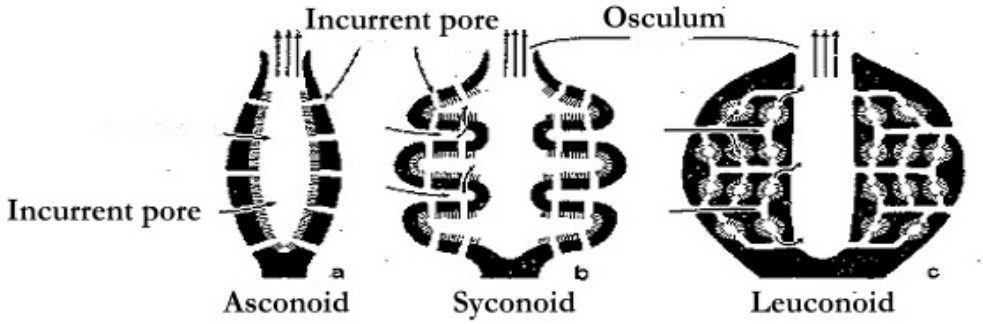


Fig 4.2.1 b Three kinds of sponge's tubular structure

Moreover, the selection process also shows when designers choose their source. Sometimes, the mapping stages often go on at the same time (Fig 4.2.1 c). The process of selecting information containing spatial metaphor is also the reason why selection stage and mapping stage often happen together. The mapping thinking is a complicated process of alternate source and target. The designers read the source and ponder the characters of design purpose, and then go back to think the source and think the function of the purpose again. It is an important process in analogical thinking because the process decides how deeply the analogical results would be. The mapping stages often related to the selection stage and sometimes are happened together with selection stages or learning stages because mapping is a connecting stage that the subjects link between source and target.

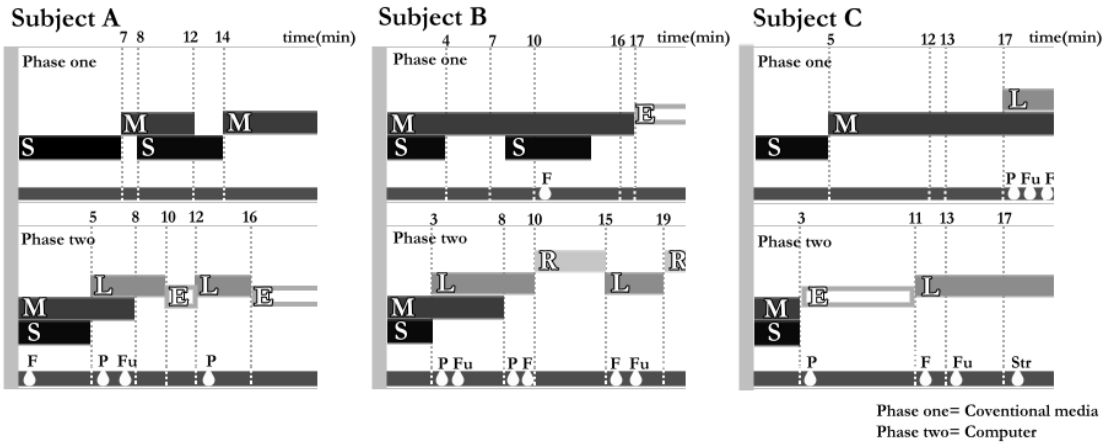


Fig 4.2.1 c mapping stage sometimes happens together with other stages

Therefore, designers select the information symbolizing spatial meaning in source material and meanwhile they think about the possibilities about which images or sentences could connect to their design target. They transfer the sources to equal architectural relationship. The designers capture some spatial characteristics or relationships of the source; at the same time, they relate what architectural characteristics or relationship are equal to the resource. For example, the subject B in phase one reads the source material and then he writes down

"floating>moving, changing", "flocking together>combination", and "body containing water>pneumatic." When he tries to select some source and meantime he thinks what points are able to relate to design purpose. On the other hand, the mapping stage sometime occurs with learning stage since mapping thinking can aid the designers to generate their design concept. In phase one, after selecting the source and possible target, subject C draws several sketches to attempt to confirm the analogical relationship and starts generating his design using mapping thinking.

In the mapping thinking process, designers capture some sources and try to transfer them to the equal architectural meaning. Most designers have the same analogical ideas that they choose the same sources and associate the sources with the same transfers. Table 4.2.1 d presents some examples of popular sources the subjects choose and what the equal architectural relationship they use.

Analogical source	**The possibilities of transfers**
The form of Jellyfish	1.The umbrella structure of traditional stalls 2.Round space
Flocking together	1.Combination 2.Group
Jellyfish body is made up of 95% water	1.Transparency 2.Inflatable
Three layers of jellyfish' body	Three Spatial functions
Flexible body of jellyfish	Flexible space
Zooplankton	Morphing
Sponge's tubular structures	The structure of housing
Water flow	Air current

Table 4.2.1 d Some examples of popular sources the subjects choose and what the equal architectural relationship they use

In addition, when we discuss the relationship source and transfer, the levels of analogical ideas must be paid attention to. The coding results show that designers select source of function and property among various levels of spatial analogies than other kinds of analogies. Analogy of function is the most important level that designer concern about. Table 4.2.1 e shows the percentages of numbers of analogical levels in two phases. Analogy of function occupies the highest percentages which are 43 % in phase one and 33% in phase two. The designers read the information and then transfer some characteristics of the source organisms to some functions of their design. The level of function contains spatial metaphor and deeply

relationship between source and target. It is not like the analogy of form that is only attribute mapping. Most functional analogies imply relational mapping. For example, the flexible body of jellyfish is converted into changeable space dimension of the roadside stall. The similarity between jellyfish and umbrella signifies that the roadside stall has the function providing the wind and rain. The water movements which water enter spongocoel through incurrent pore and flow out through osculum transfer into aerial currents of the living space. On the other hand, the analogy of property also plays a key role in analogical thinking because it is the secondary one they use frequently. The spatial properties, such as color, movement, light, composition, and so forth, are the obvious features that subjects could get from source material

Phase One(conventional media)							**Phase Two(computer)**				
	P	F	Fu	Str	Fr		P	F	Fu	Str	Fr
A	1	1	3	1	0		2	1	5	3	0
B	1	2	1	2	0		3	3	2	1	0
C	3	1	6	1	0		2	1	2	2	0
Sum	5	4	10	4	0		7	5	9	6	0
	22%	17%	43%	17%	0%		26%	19%	33%	22%	0

Table 4.2.1 e The percentage of choosing analogical levels

Most designers map and create their design with various level analogies. The analogy of property, form, and function are often appears before than the analogy of structure since most designer concern design functions and forms than structure. According to the coding result, the levels of form (F) and property (P) emerge in the early part of the process, the level of structure (Str) appear in the latter part of the process. Most designers build their transfer with attribute mapping, such as the form and property, and then they concern about deeper analogies. Another reason is that most designers concern design functions, forms, property than structure.

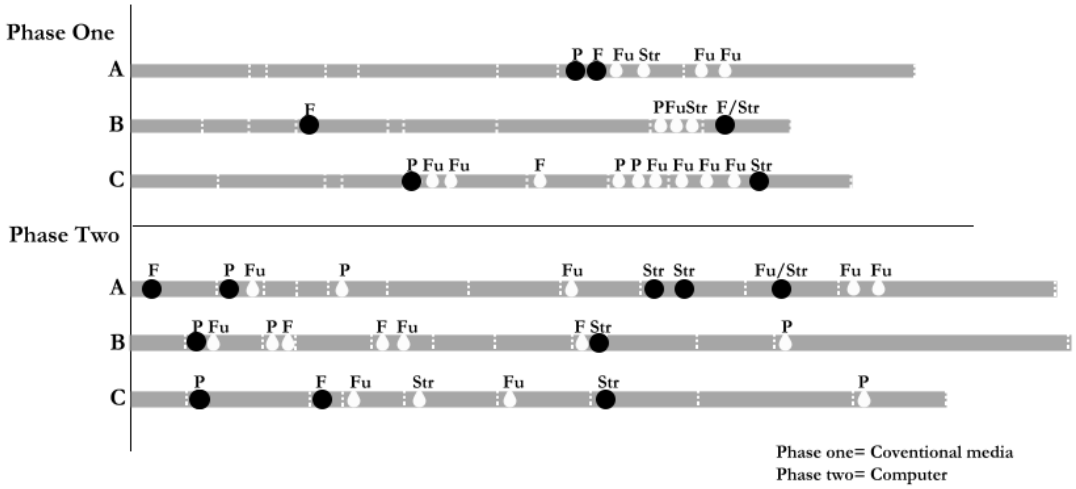


Fig 4.2.1 f the order of appearance of analogical ideas

4.2.2 Phenomenon Two:

The analogical ideas occur concentrated in the latter part of the process in conventional media. On the contrary, the appearances of analogical ideas scatter in different move in computer media.

All subjects spend much time in mapping stage with conventional media (phase one), but they consume few time in mapping stage with computer (phase two) that displaces is more time consuming in learning stage (Fig 4.2.2 a). For instance, subject B in phase one consume twenty-seven minutes in mapping stage and eight minutes in learning stages, but he in phase two costs only seven minutes in mapping stage and thirty-five minutes in learning stage. The opposite situation result from the characteristics of two different media. The conventional media aid the subjects with sketching many diagrams that improve subject's mapping but not help them form their final concept efficiently. Subject A and Subject B spend much time in mapping stage with conventional media because they draw many diagrams and imagine many possibilities. But it does not mean that they could confirm the final design concept easily. On the other hand, it is difficult that using computer media to generate many diagrams, the whole process has only one model. When the designers start to build the model, they have already entered the learning stage. They think and try as they build their concept design, so they spend more time in learning stage in phase two.

In addition, more fragments appear in the phase two (computer). Some evaluation stages emerge between learning stages that cause more fragmental stage. To cite one example, subject A has two times of evaluation stages happen in phase two. When he tries to generate his design concept, he often discontinues his learning stage because of trying the various

computer parameter and different instructions. However, rare evaluation stages happen in phase one. Subject B encounter evaluation stage in phase one because he search too many analogical possibilities but does not know how to combine them. Then, he abandons one of them to generate his design by few analogical ideas.

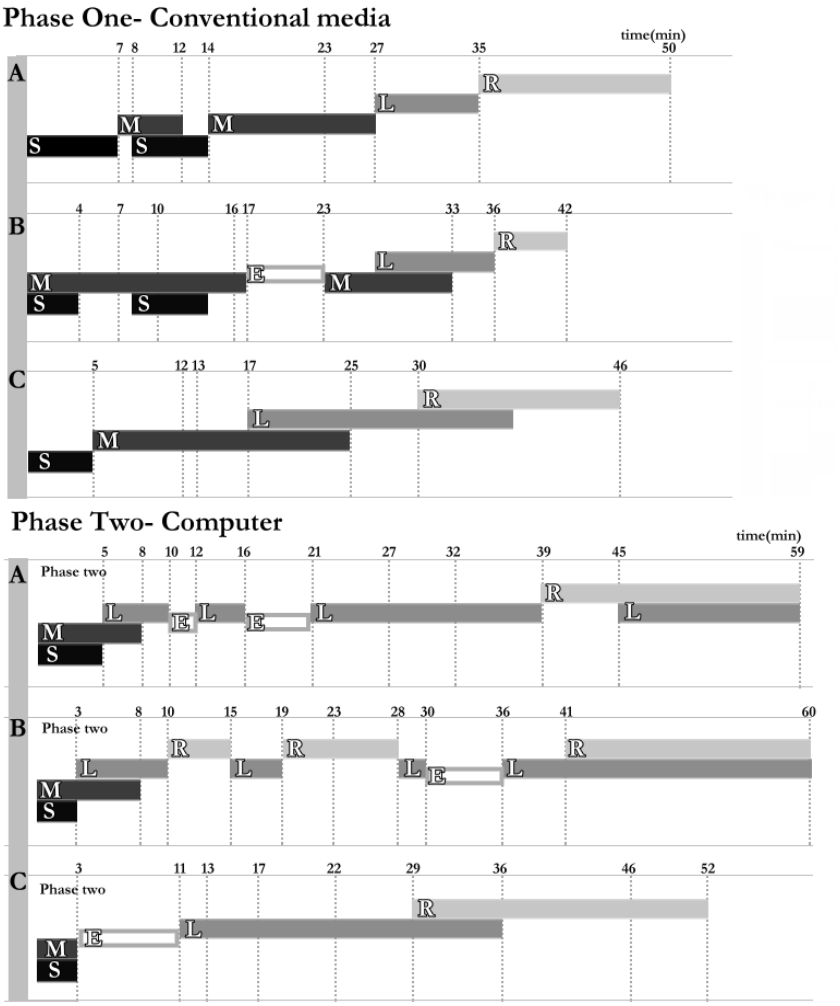


Fig 4.2.2 a Coding results

Figure 4.2.2 b presents appearance of analogical ideas in six experimental sections. In the phase one, the analogical ideas occur concentrated in the latter part of the process. On the contrary, the appearances of analogical ideas scatter in different move in phase two, and some of them appear at the beginning of the process. In phase one, the subjects draw many diagrams at beginning but they confirm their design concept at latter process. It means the analogical ideas may be established in their mind but not be specified the final analogical result until the latter process. Thus, most analogical ideas do not happen in the early design moves and aggregate in latter process. On the other hand, when the subjects generate their design with computer media, they decide one or two analogical ideas as their design base to

constructer the model at beginning. Then, they put other analogical ideas through the process, and these analogical ideas are distributed in whole process.

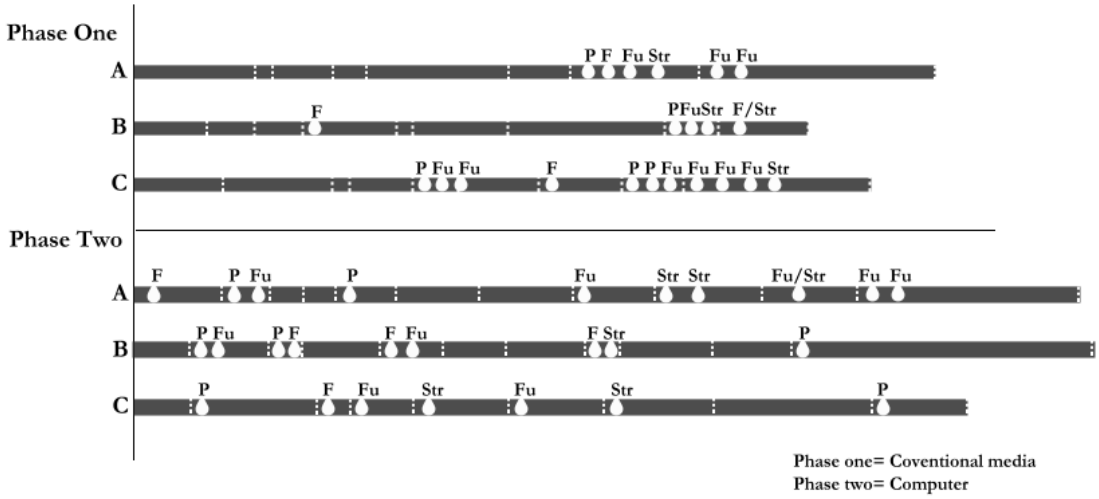


Fig 4.2.2 b the appearance of analogical ideas

As discussing the issue of the relationship between stages and ideas appearance, the author proposes an interesting situation by the coding result (Fig 4.2.2 c). In the phase one, most analogical transfers happened in learning and representation stages, but the analogical transfers appear in selection, mapping, learning and representation stage in phase two. As was stated above, the analogical ideas occur concentrated in the latter part of the process, but the appearances of analogical ideas spread in design process in phase two.

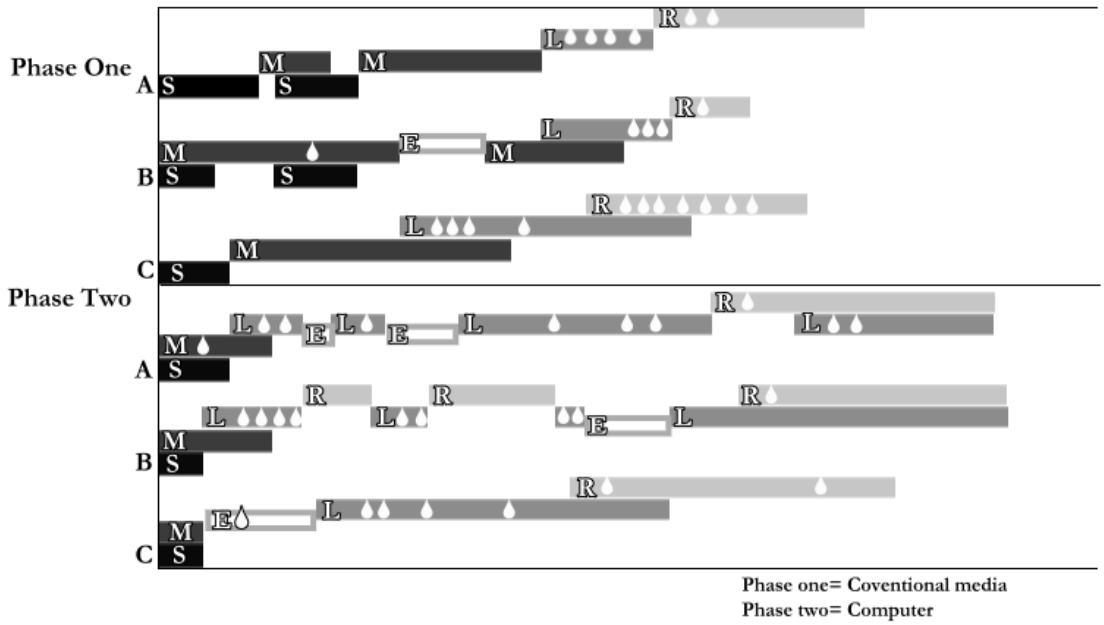


Fig 4.2.2 c Relationship between appearance of analogical ideas and the stages

4.2.3 Phenomenon Three:

Every medium possesses different characteristics that lead the analogical thinking process and design results to become diverse. It found that conventional media could assemble the analogical ideas and the computer media could broaden the possibilities of analogical thinking.

In this section, the author discusses how the characteristics of media affect analogical thinking process. Different characteristics of design media offer the variability of analogical thinking process. It could change the design process and design result. In this research, the author discusses analogical thinking in conventional media and computer tools. It found that using conventional media improves to collects different analogical ideas together, and using computer media can make the design result more variously.

According to previous review, many features of conventional media are very different from computer applications. The conventional media could help designers generate many sketches that learn the form of analogical source, capture the analogical features, or use them to develop design. It also means that designers using conventional media spend more time on mapping stage, which is pondering process. They spend much time on sketching sketches and diagrams. The freehand sketch possesses the characteristic of dense, ambiguous, and amorphous that can stimulate the ideas collection. In addition, the freehand sketch could be modified easier and draw faster than computer media that help designers change their thinking through simple sketching faster. At the beginning they draw some diagrams which are similar to the source organisms and finished off these diagrams with a few deft strokes of the brush. Because these free strokes contain the train of thought of the designers, every stroke may be the inspiration of the next sketch and designers could find interesting information form these diagrams. Then, they apply this information to draw new diagrams and transfer the original source to a new condition. The sketches they draw are gradually far from the original appearance of the source organisms to their own design concept.

For example, fig 4.2.3 a is the mapping process of subject B. He draws the jellyfish's shape at firstly. He learns and copies the form of jellyfish to gain some source information. Next, he generates several diagrams to study jellyfish's characteristics to not only improve his understanding about jellyfish but also stimulate his design ideas and combine these ideas together. It is the process that the designer learns the jellyfish's form to transform it into his spatial analogy and integrate them into final concept. Fig 4.2.3 a is similar mapping process of subject A.

Fig 4.2.3 a the mapping process of subject B

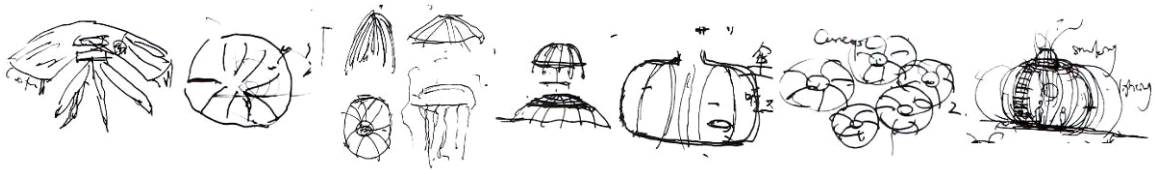


Fig 4.2.3 b the mapping process of subject A

Therefore, designers using conventional media can draw many sketches and diagrams, and gather many analogical ideas together at one time. Assembling keywords and sketching sketches lead to designers clarify their various analogical ideas and improve their personal ability to integrate these ideas. After combining the ideas and accreting the analogical relationships, they start to generate their design concept and present the definite analogical transfers on the paper. It is also the main reason that most specific analogical ideas appear in latter stages on whole design process.

The studying method in conventional media helps designers to clean their thought and gather together the analogical ideas, but it could not aid to draw more complex design and has difficulties to present sense of three-dimensional space. The freehand sketch shows the design by only one angle and the real three-dimensional space still only exist in designer's mind. While the designer tries to draw complicated concept, the perceptual ambiguity of conventions sketching may occur when multiple two-dimensional views are used to represent more complex objects. Subject B using conventional media only finish his conceptual design in ambiguous condition since it is difficult to precisely present the complex concept through two-dimensional sketch, such as the flexible shape which could be changed freely. Thus, the final result of his design is too abstract to comprehend and the author could not understand easily without his explanation.

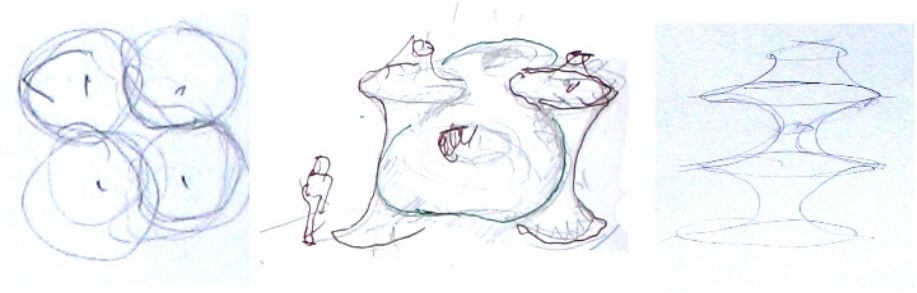


Fig 4.2.3 c Ambiguity of conventions sketching

Subject B also meets other difficulties in design process and try another possibility. He gets a revolving feature of jellyfish life history and tries to apply this feature to his design, but he draws some diagrams and could not develop his idea with sketching. Finally, he abandons the idea and chooses other new idea to develop his design.

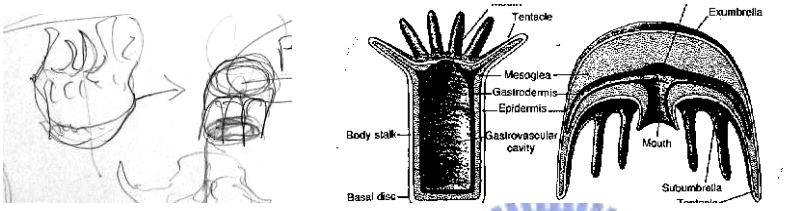


Fig 4.2.3 d Difficulties of manipulate complex concept

Moreover, designing with conventional media reduce possibilities of spatial transformation because the next sketch come from the previous sketches. The final result is the accumulation of the previous works. It is difficult that the final result has huge differences from the designer's expectation at first. In addition, the thinking with conventional media is abstract because designer draw their sketches with few angles and the blur lines are difficult to ascertain their design concept.

As given above, conventions sketching make designers draw many diagrams or sketches. However, it becomes easier to consider the shape as a preliminary one which is under constant revision, rather than as a fixed shape. Therefore, computer media make the analogical thinking process become different from the traditional process.

According to phenomenon two, analogical thinking using computer media has very different process from conventions sketching. The designers use computer media to expand their design with only one model, and add every analogical idea to their design in different phase of design process. They seek a key analogy to start to generate their design and then add put other transfers individually in whole process. In addition, designers using conventional sketching spend much time on sketching many sketching which process also called mapping

process, but they using computer media sometimes consume much time on trying that is involved in the learning stages in analogical thinking process.

Computer media improve the possibilities and diversities of design results. When designers generate their design with conventional media, what they draw affects their next step of their design. It is a step by step process that the final design result is decided by the previous study. Every word they write, every stroke they draw and every move they make influence their design result. The concepts are developed gradually by the designers. However, computer allows the designer to explore numerous creative solutions to problems, overcoming design fixation or limitation of conventional wisdom by generating these alternative solutions for the designer. When designers create their design with computer media, they know the design direction but cannot expect the possible final result about their design. The designers proficient at computer media manipulate the application's commands and parameters to change the form or other spatial functions. Using mathematical algorithms, the computing tool has an enormous capacity to describe things of extremely diverse nature. For example, one function of three-dimensional application, a NURBS (non-uniform rational B-splines) modeller, means that 3D free-form organic surfaces and solids can be created intuitively and quickly at the early design stage, a serious limitation of the traditional polygon modellers.

When designers adjust a parameter or input a command, the design may become a new look that they cannot imagine before it. Figure 4.2.3 e shows that Subject B change the shape of his model by control parameter.

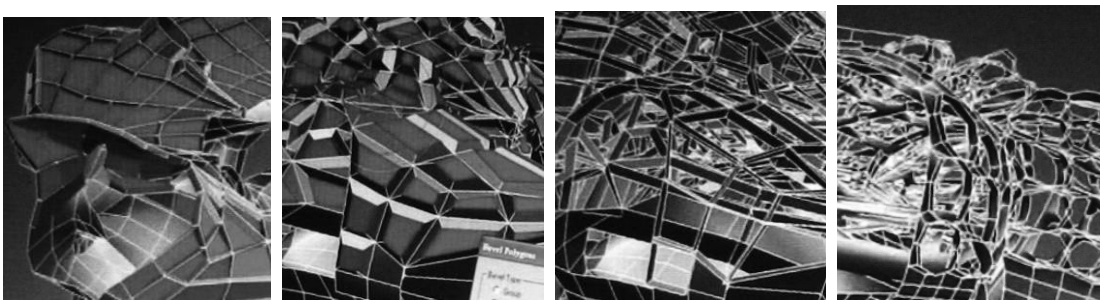


Fig 4.2.3 e Subject B change the shape of his model by control parameter

Nevertheless, computer has its own limitation. The character of computer broadens analogical transfers but it is only for some designers conversant with one or more complex applications. The better analogical thinking design is not only affected by the designer's ability but also influenced by familiarization of computer media. The more commands or parameters the designers know how to use, the more analogical possibilities they show. To cite one example, subject A and subject B handle the computer applications well and both of they use 3Ds Max

to be their main design media. 3Ds Max possesses complex interface and has sorts of functions to build any kinds of models. Both of them often design with only computer and think the computer media make their design results more deeply and broadly. They finish their design with a complete model and their analogical design is complicated than their previous one with conventional media. In contrast, the design situation of subjects differ from Subject A and B. Subject C indicates that the thinking process of two phases is similar. Even in different media, he captures the same kinds of spatial key words from the source material and connects them with design topic. But the limitation of Sketch Up which the application he use does not proficient at generate free form sharp, he has difficulties in creating the imaginary sharp which he want with only computer media. It is an obstacle to interrupt his analogical thinking.

Table 4.2.3 f shows the tools and applications that three subjects use and indicates the obstacles some of them encounter in design process.

	Phase one(conventional media)		**Phase two(computer)**	
A	Fountain pen		3Ds Max	
B	Pencil	He could not draw the complex form with conventions sketching.	3Ds Max	
C	Fountain pen		Sketch Up 3Ds Max	He could not create the image he really holds in mind with computer.

Table 4.2.3 f Obstacles the subjects encounter at design process

Table 4.2.3 g shows the analogical ideas that three subjects generate in two phase. Subject C generate more analogical ideas with conventional media. Subject A and subject B generate more analogical ideas with computer.

Phase One (conventional media)							**Phase Two (computer)**					
	P	F	Fu	Str	Fr	**Sum**	P	F	Fu	Str	Fr	**Sum**
A	1	1	3	1	0	**6**	2	1	5	3	0	**11**
B	1	2	1	2	0	**6**	3	3	2	1	0	**9**
C	3	1	6	1	0	**11**	2	1	2	2	0	**7**

Table 4.2.3g

Moreover, because the designers need to spend much time on different analogical possibilities, the process is more time consuming. Designers spend much time on studying different commands or parameters to pursuit their design results. On the other hand, they also spend much time on observe their design model and rotate their model with different view or scale. The computer media could help designers know more about the relationship of space and spatial dimensions. Designer can examine their design models with different scale and view. It also helps the designer build complex model.

Chapter 5: Conclusion and suggestion

Base on the above results and analysis, the author proposed the some phenomena of analogical thinking and brings some different view about the role of analogy in design field. In the chapter, the author makes a conclusion about this research and then discusses limitations and future works of this research.

5.1 Conclusion

In this research, the author focuses on understanding analogical thinking in design field and proposes some new opinions about analogy. Analogy is a common thinking process for designers and stimulates designers' innovation, but few scholars discuss the analogical thinking process in design domain. This research investigates this issue, tries to know more the design process of designers, and proposes some view of points of analogical thinking process. Two main purposes that the author tries to investigate deeply are the analogical thinking process and variation of analogical thinking with different media.

From the result of the analysis of visual and verbal data from experiments, the author derives three cognitive phenomena of designers while he/she generate concepts with computer or conventional media. The three phenomena shows that the analogical thinking in design domain has some special characteristics that analogy in other fields, such as linguistics, semantics, literary or mathematics, do not possess. The first phenomenon is that designers search some key words or meaningful pictures that contain spatial metaphor to be their analogical sources. Secondly, the analogical ideas occur concentrated in the latter part of the process in conventional media. On the contrary, the appearances of analogical ideas scatter in different move in computer media. Finally, different kinds of media possess different characteristics that lead the analogical thinking and design results to become diverse. Conventional media assembles the analogical ideas; the computer media broadens the possibilities of analogical thinking.

Analogical thinking processes in different media have many points in common. The main common point is that the designer's thinking and analogical decisions. Even though designers design with different tools, the analogical ideas which they choose and transfer are the same. According to this phenomenon one, it found that the most analogical transfers aim at visual and spatial analogy. Designers pay particular attention to the words or images which have spatial metaphor. Most of designers in the experiment capture the same images or key words,

but how they apply the source to their target and how deep their analogical transfers would be are decided by designers' creativity and ability. Therefore, the design tools may affect the design process and the result of analogy, but it could not decide the main thinking of designers' mind.

The different points of analogical thinking process are the results of design and some differences of whole process due to the disparities of design medium. The phenomenon two and the phenomenon three show how media influence the analogical thinking process. On the one hand, freehand sketching helps designers to draw many sketches and clear their thinking; therefore, the designer can generate more concepts when he/she uses conventional media. On the other hand, the experimental results prove that generating analogical ideas does not only happen in sketches. Previous research proposed some limitations of computer; however, from this research, the author not only makes people know more about analogical thinking with computer but also proves how the computer breaks the traditional view that offer analogical thinking other possibilities. For the immediate visualized feedback of computer, the designer can easily been influenced to have some imaging in his/her mind. Abundant functions of computer applications aid designers in stimulate their design creativities. It needs to concern the impact of computer on areas of drafting, visualization, three-dimensional (3D) modeling and performance analysis, all of which are seen as important elements affecting analogical results.

Finally, the contribution of the research is a preliminary understanding of analogical thinking in design field. According to the results of analysis, analogical thinking is an interaction between designers, analogical sources, design target, and design media. Designers play the most important role in analogical thinking process because they can choose and transfer the idea which they are interested in. The analogical depth also depends on the designer's imagination and creativity. The design media play a supporting role in analogical thinking process. It means that the characteristics of design media not only affect design process and design result but also offer the variability of analogical thinking design.

5.2 Limitations

There are some limitations on this research. Firstly, this research is a discussion about the relationship between analogical thinking and design media. Because there is still no theory describing how analogical thinking works in this field, the author use the common research method "protocol analysis" and apply some analogical theories from other fields. The

segmentation of coding scheme could help abridge the huge data, but it also leads to some details are neglected.

Secondly, another limitation is each of the subjects are good at different design tools, it is possible that the subjects' responses are affected by the tools that they use. Every design application has different characteristics and diverse functions. For example, the application 3Ds Max provides designers plenty of parameters or commands. The application Sketch Up offers designer a simple computer design environment to manipulate, but it does not possess various functions. The author rarely discusses this issue because the main purpose of this research is to investigate the analogical thinking from the perspective of design media but not a comparison between different computer media. Thus, this issue should be further examined.

Thirdly, the analogical sources are limited on organic analogy because the author tries to understanding the analogical thinking process. The diversity of organism could offer designers have more sources ideas to choose in a limiting condition. Moreover, paying attention to various sources would lead to distract from our main problem. However, the only organic analogical source is not comprehensive enough. After preliminary understanding of analogical thinking, the further study will focus on various types of analogical sources.

Finally, owing to few numbers of subjects in this experiment, the results in this paper should be regarded as a consequence in a case study. The author picks three subjects from eight subjects that are few numbers, but for the preliminary study, it is already sufficient. More designers will be invited in the further study.

5.3 Future studies

The research discusses some phenomena of analogical thinking in design field. It is a pilot study of this issue. Our further study will focus on broad approach of analogical thinking, such as variability of analogical sources. There is a need for further 'applied research' into this area where proper research methods and techniques should be employed on a bigger sample using different media. More architectural designers will join the research and more kinds of media will be investigated. It is hoped that this research has to some extent established a 'framework' of analogical thinking process in design field. Also, experimental research is needed in architectural offices, where the context is different and the subjects are experienced architects whose design knowledge/experience is greater than that of only 'novice' students.

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Appendix

1. **Experiment**
2. **Material source**
3. **Brief interview**
4. **Coding result**

Appendix 1: Experiment phase one

實驗流程說明書

非常感謝您願意參與這個研究的實驗，
由於您的配合，此設計研究將有新的斬獲。
接下來將對您說明整個實驗的流程以及目的，請務必詳讀。
在整個實驗說明中若是有任何不懂的地方，請您提出，研究者會為您說明。
若您已經準備好，請翻至下一頁，
我們將開始說明整個實驗並且使您熟悉實驗的運作方式。

首先，感謝您抽空參加這一次的實驗，在本實驗得到的所有資料，將使用於設計思考的研究上。實驗中將會用一台攝影機、一台相機、一組錄音機將所有過程加以錄影，研究者同時也需要將您所繪製的草圖留下來作為分析資料。

草圖以及錄影帶只會使用在這個研究上，成為研究者所需的研究分析資料。研究者需要的，並非您所創作的設計內容，您將保有絕對的創作概念財產權，以及您所繪草圖的著作權。

請在下列表格簽名，並填寫個人資料，研究者稍後將開始攝影。

請寫下您的姓名：

日期：

電話：

年齡；

性別：

學歷&工作：

背景（專長領域、時間）：

這一份實驗流程說明對於本實驗非常的重要，請確定您已詳讀，並了解這個實驗期望您能配合的各個要求。謝謝！

這個實驗的目的主要是想要了解您在設計時的類比這行為如何引發您的設計構想。為了達到這個目的，實驗必須採用下列的方式進行。首先，需請您先執行一項設計任務，此階段需盡可能腦力激盪出各種創意發想；在設計完成後，研究者會跟您做一個五到十分鐘簡單的訪談，請您參考您的草圖資料對您的設計提出一些講解和描述。

運用傳統媒材設計：(紙、筆、粉彩、尺...等手繪製圖工具)

在下一頁中，有一個待完成的設計題目，請您假設這是即將對您所服務的設計公司所要提出的設計提案，如同您在之前執行的設計工作一樣。研究者會提供一些相關的資訊和資料給您，若研究者提供的資料不能滿足您的要求，請您像一般做設計的情況下透過自己本身的認知去繼續進行。

在實驗過程中，與平常進行的設計情境是相同的，若是對於設計題目沒有相關問題以及要求的時候，請您當作研究者不在現場，而研究者將會在房間內，但遠離設計者工作場所的地方，等候您在設計過程中有任何問題隨時皆可提出，也請您不要因為錄影或是錄音而有任何的拘束感。

這個實驗的時間設定為40分鐘以內，研究者將會在還剩最後5分鐘的時候提醒您，此時若您願意的話，即使時間超過，您還是可以再10分鐘的時間完成您的設計構想。在這個實驗過程中，希望您能不斷的發揮想像和創意去設計去完成您的作品。

若是您還有任何問題的話，請您盡可能現在提出。

現在將開始進行這個設計題目的提案，請您翻到下一頁後，盡可能約在 40 分鐘內完成這個設計到構想階段。

設計主題：水母概念-新型態攤販

1、 構想來源：

設計師常需要藉由不同的題材去引發創意，而這是非常重要的過程，當然這種過程不僅僅包含表面的外觀上的類比，更有深入的關係、構造、型態的概念引用延伸，甚至藉由一種物件的型態或關係去延伸出設計方法。本設計想讓設計者挑戰自己的潛力，藉由限制設計者的創作來源去激發設計想法，因此，本設計將創作來源限定為「水母」，設計者可參考此種生物的生活型態、演化、特質、構造、活動、生長過程、外型...等等，擷取「水母」任何層面的相關資訊作為自己設計發展來源。設計者參考提供水母的相關資料，請參考資料中的文字圖片去引發思考。

2、 設計主題概述：

各種類型的攤販存在於台灣社會中很長一段時間，但目前的攤販除了外型美觀問題外，機能、衛生、和便利性都有待加強。因此本設計將挑戰設計者的創意去改造台灣的特殊的買賣空間，將傳統認知的「攤販」型態轉型，並設計出顛覆傳統價值觀的新型態攤販。設計者可以運用自己的想像和認知去自由設計，不用受到傳統攤販形式的影響。並在這種新型態的攤販中加入特殊的機能，例如可移動、可伸縮、可容納更多客人、阻擋髒空氣、可適應各種地形、可多個攤販並存…等。而本題目限制藉由上述的「水母」做引發，可藉由水母的任何關係去發揮，但不需要全盤引用，有時只是一個或部分概念的延伸即可。

3、 設計目標：

1. 引用任何「水母」的概念完成設計到初步概念階段
2. 設計一能滿足基本機能的新型態的攤販設計
3. 發揮創意和想像，加入特殊的攤販機能

4、 基本機能：

1. 如展示擺放空間、收納空間、賣家的工作空間
2. 顧客的購買空間、長期或短期停留空間

5、 圖面要求：

1. 最後需至少完成一張以上（包含一張）的透視草圖

Appendix 1: Experiment phase two

第二階段實驗流程說明書

非常感謝您願意參與這個研究的實驗的第二階段，
接下來將對您說明整個第二次實驗的流程以及目的，請務必詳讀。
在整個實驗說明中若是有任何不懂的地方，請您提出，研究者會為您說明。
若您已經準備好，請翻至下一頁，
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首先，感謝您抽空參加第二次的實驗，在本實驗得到的所有資料，將使用於設計思考的研究上。實驗中將會用一台攝影機、一台相機、一組錄音機將所有過程加以錄影，研究者同時也需要將您所繪製的草圖留下來作為分析資料。

草圖以及錄影帶只會使用在這個研究上，成為研究者所需的研究分析資料。研究者需要的，並非您所創作的設計內容，您將保有絕對的創作概念財產權，以及您所繪草圖的著作權。

請在下列表格簽名，研究者稍後將開始攝影。

請寫下您的姓名：

日期：

這一份實驗流程說明對於本實驗非常的重要，請確定您已詳讀，並了解這個實驗期望您能配合的各個要求。謝謝！

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運用電腦媒材設計：(3Ds Max, Maya, Sketch Up..等電腦媒材工具)

在下一頁中，有一個待完成的設計題目，請您假設這是即將對您所服務的設計公司所要提出的設計提案，如同您在之前執行的設計工作一樣。研究者會提供一些相關的資訊和資料給您，若研究者提供的資料不能滿足您的要求，請您像一般做設計的情況下透過自己本身的認知去繼續進行。

在實驗過程中，與平常進行的設計情境是相同的，經過上次的實驗，您更可習慣與了解這個過程。相同的，若是對於設計題目沒有相關問題以及要求的時候，請您當作研究者不在現場，而研究者將會在房間內，但遠離設計者工作場所的地方，等候您在設計過程中有任何問題隨時皆可提出，也請您不要因為錄影或是錄音而有任何的拘束感。

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現在將開始進行這個設計題目的提案，請您翻到下一頁後，盡可能約在 40 分鐘內完成這個設計到構想階段。

設計主題：海綿概念-短暫居住空間

6、 設計主題概述：

因人口的膨脹和居住型態的多元化，各種居住型態的可能性將被探討，本次設計希望設計者激發創意與想像力構思出一種簡單方便的**小型短暫居住空間模式**，而這種空間是有可能存在不同的環境中，可提供各種人停留或短期居住的遮蔽保護空間，例如給許多旅人、流浪者、僧人、難民、牧人..等等使用，這就類似「帳篷」概念的延伸和想像(但不需要一定要具備帳篷可隨意收納的特性，因為**多元化的短暫居住方式**才是本設計的探討目的)。而設計出來的居住單元是要有機會被複製或是被改變成不同的型態，以利提供大眾使用。設計者也可根據自己對「新型態短暫居住空間」的想法和創意去引發各種可能性和新的機能。

7、 構想來源：

本次設計將創作來源限定為「海綿」，設計者可參考此種生物的生活型態、演化、特質、構造、活動、生長過程、外型...等等，擷取「海綿」任何層面的相關資訊作為自己設計發展來源。而本設計請由參考資料中「海綿」的概念去發想引伸，並完成這次的設計到概念階段。

8、 設計目標：

4. 引用任何「海綿」的概念完成設計到初步概念階段
5. 設計一能滿足基本需求的小型短暫居住空間單元（供三人以下使用）
6. **發揮創意和想像，加入特殊的型態或機能，例如如何處理空氣流通、外觀多變性、功能多變性..等等**

9、 基本機能：

1. 包含最基本機能的簡單居住空間
2. 可通風、遮風、擋雨等基本「保護功能」

10、 圖面要求：

1. 最後需要完成到概念模型階段

Appendix 2: Material Source-phase one

請閱覽此份參考資料。這是研究者為您精簡條列的相關資訊，前半部為文字資料，後半部為圖片資料。關於文字部份，您可藉由劃線的重點提示來迅速瞭解「水母」的基本概念，或者藉由此方式去快速找尋您所感興趣的連結。

請認真利用此份資訊，以幫助您做這份設計時「類比概念」的成形是有深度上的可能性。

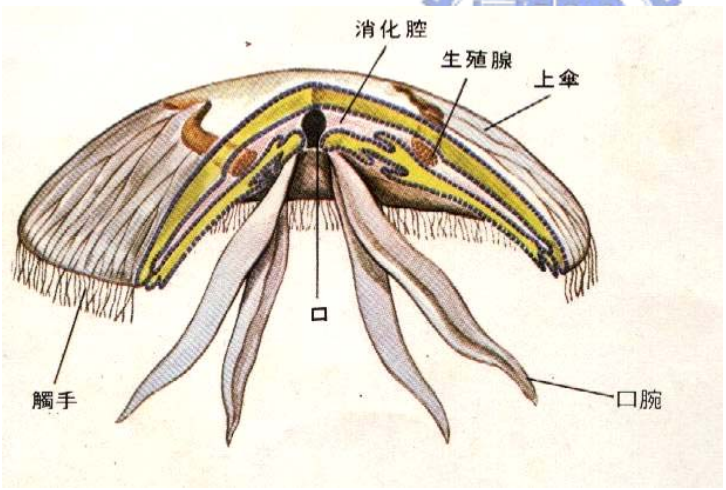
視覺及參考資料:

1. **水母(jellyfish)是海洋中的大型浮游生物**，全世界大約有 250 種。牠們的壽命大多只有幾個星期，但也有能活到 1 年的種類，有些深海的水母可活得更長些。

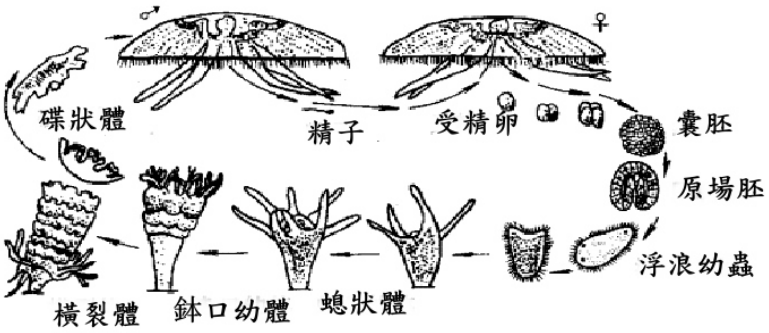
2. **水母是群聚動物，**由於水母經常大批漂洋過海，有時還會擠在一起綿延數裏甚為壯觀

3. **水母的身體有 95%以上是水份，**其他則是蛋白質和脂質所構成，所以水母的身體會呈現透明狀，就是因為身體內的水份之故。

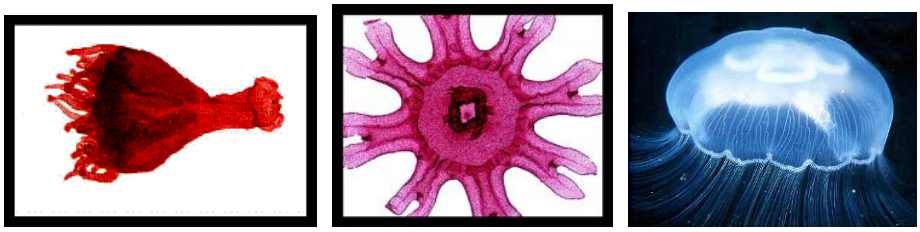
4. **水母具有三胚層**，最外是表皮層(epidermis)，最內層則是胃皮層(gastrodermis)，由胃皮層構成一簡單的體腔，只有一個開口，兼具口及排泄的功能，在表皮層及胃皮層之間的則是中膠層(mesoglea)。兩胚層間有很厚的膠層，不但透明且有漂浮作用。在運動時，利用體內噴水反向前進，遠觀就好像一頂圓傘在水中漂遊。



5. **水母的生活史有兩個階段，水螅型和水母型，前期是水螅型無性生殖肴無性世代，後期則是水母型有性生殖肴有性世代。**水螅型包括螅狀幼體和橫裂幼體兩期。螅狀幼體棲息在海底硬質物體上營生。螅狀幼體以**橫裂生殖**方式形成橫裂幼體。橫裂幼體成熟後，把**頂端的碟狀個體依次往水中釋放脫離母體**，形成碟狀幼體，也就是小水母。小水母就是後期(有性世代)的起點，是浮游動物，長大後的水母一般是雌雄異體，精卵排出體外行體外受精。受精後的受精卵發育成浮浪幼蟲後沉入海底，固著在堅硬基底上形成螅狀幼體，如此循環不已進行世代交替的生活。

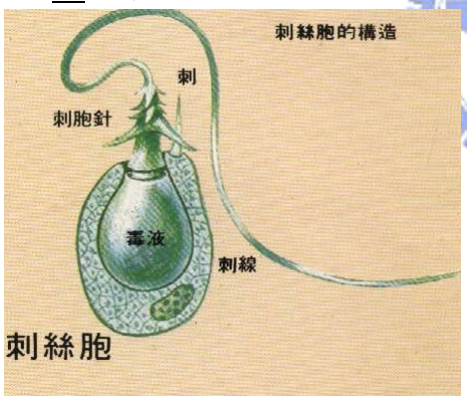


6. **<u>水母的生長過程形狀會依照不同的時期有所不同</u>**，如下所示海月水母為例：



水螅體＞碟狀體＞成年

7. **<u>在水母的傘狀體的下面，那些細長的觸手是它的消化器官，上面佈滿了刺細胞</u>**，像毒絲一樣，能夠射出毒液，獵物被刺螫以後，會迅速麻痺而死。



8. **<u>水母的共生夥伴是小牧魚，體長不過７釐米</u>**，可以隨意遊弋在水母的觸鬚之間。遇到大魚遊來，小牧魚就遊到巨傘下的觸手中間去，當作一個安全的"避難所"，利用水母刺細胞的裝置，巧妙地躲過了敵害的進攻。有時，小牧魚甚至還能將大魚引誘到水母的狩獵範圍內使其喪命，這樣還可以吃到水母吃剩的零渣碎片。

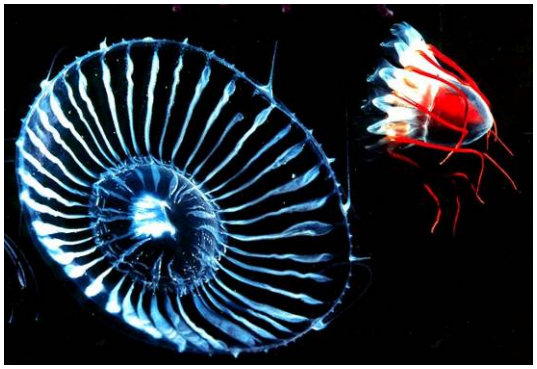
9. **<u>威猛而致命的水母也有天敵</u>**，一種海龜就可以在水母的群體中自由穿梭，輕而易舉地用嘴扯斷它們的觸頓，使其只能上下翻滾，最後失去抵抗能力。

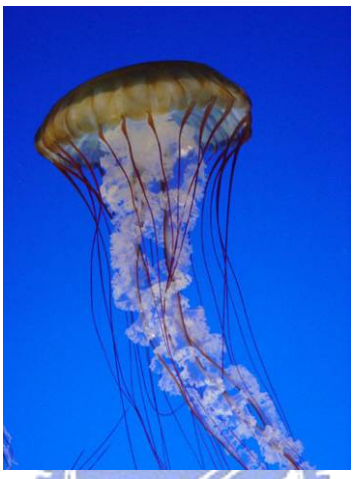
10. **水母觸手中間的細柄上有一個小球，裏面有一粒小小的聽石，這是水母的“耳朵”**。由海浪和空氣磨擦而產生的次聲波衝擊聽石，刺激著周圍的神經感受器，使水母在風暴來臨之前的十幾個小時就能夠得到資訊，於是，它們就好象是接到了命令似的，從海面一下子全部消失了。科學家們曾經模擬水母的聲波發送器官做試驗，結果發現能在 15 小時之前測知海洋風暴的訊息。

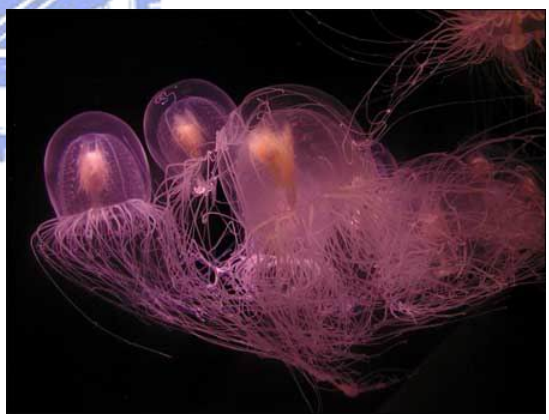
11. **水母雖然是低等的腔腸動物，卻三代同堂**。水母生出小水母，小水母雖能獨立生存，但親子之間似乎感情深厚，不忍分離，因此小水母都依附在水母身體上。不久之後，小水母生出孫子輩的水母，依然緊密聯繫在一起。

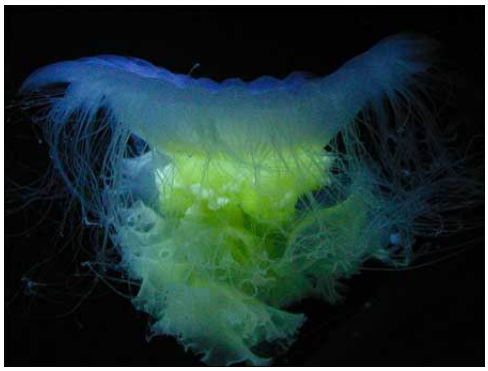
12. **許多水母都能發光**。櫛水母在海中遊動時，8 條子午管可以發射出藍色的光，水母發光靠的是一種叫埃奎明的蛋白質，這種蛋白質和鈣離子相混合的時候，就會發出強藍光來。埃奎明的量在水母體內越多，發的光就越強，每只水母平均只含有五十微克的這種物質。目前新加坡的生物學家正在進行一種實驗，把水母身上的發光基因移植到其他魚類的體內。

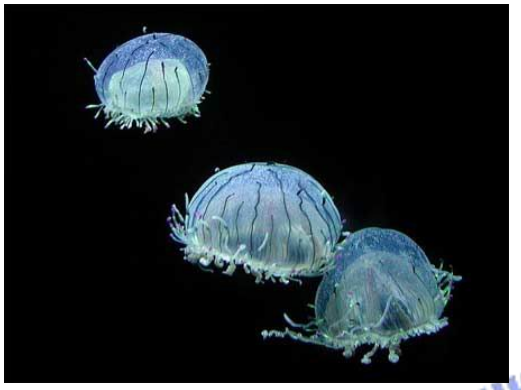
補充各類水母圖片：







Appendix 2: Material Source-phase two

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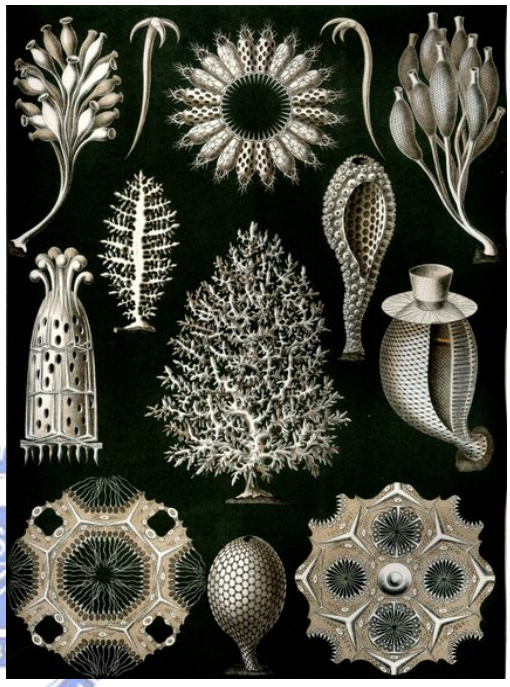
視覺及參考資料:

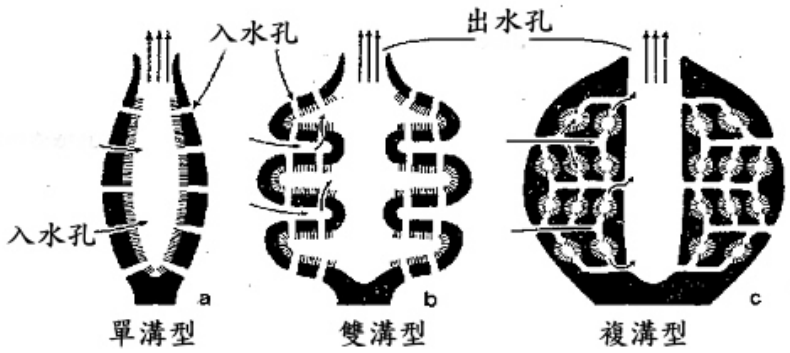
13. **海綿**為多孔動物門，也稱原生動物門，**是多細胞動物中最原始、最簡單的一個類群**。雖然經歷了幾億年的進化，組織器官仍然沒有分化，沒有口和消化腔。雖是動物，但卻基本不動，海水的流進流出靠內層細胞的鞭毛擺動來進行控制。

14. **海綿動物的形狀千姿百態**，有片狀、塊狀、圓球狀、扇狀、管狀、瓶狀、壺狀、樹枝狀…等等不同的型態。通常水流流速的大小、波浪活動的強弱、底質的硬軟程度，也常使同一個物種的海綿擁有不同的外部形態。在流急環境中生活的又大都像土墩，有著良好的流線形體型；而在緩流或風平浪靜的環境中棲居的，體形又多呈高聳的煙囪狀。

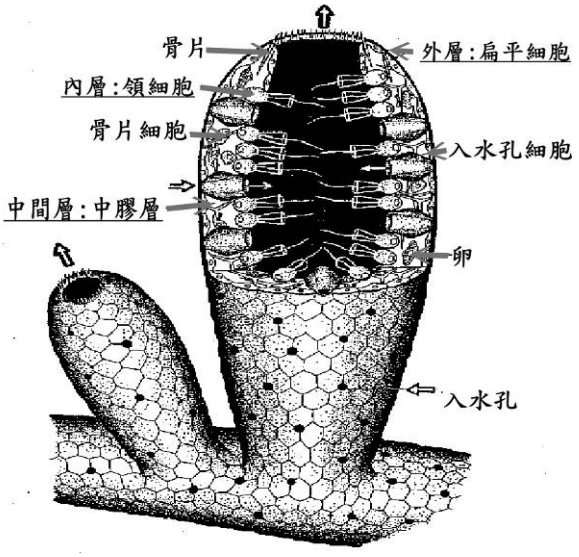


15. **海綿動物的色澤各個不同**，有大紅、鮮綠、褐黃、乳白、紫色等各種顏色。其色彩來源於共生藻或非活性的貯存色素，例如綠色是因其體內共生有綠色的蟲綠藻，而紅色、黃色、桔黃色等是因為細胞內含有脂溶性的胡羅蔔素，其存在可產上各種顏色。

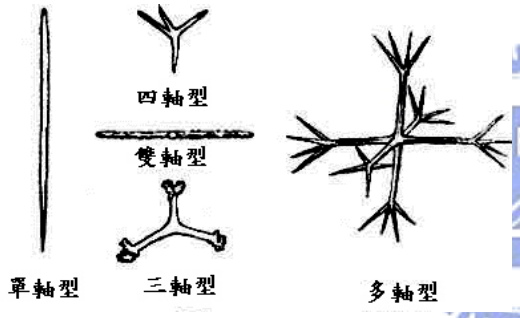
16. **海綿不具備執行各種機能的器官，其最重要的結構是水管系**，主要由入水孔、領細胞和出水口組成。根據領細胞的排列方式和水管的發育程度，水溝系從簡單到複雜，可分成單溝型、雙溝型和複溝型 3 個基本型(如下圖)。入水孔通入體內的溝道，同領細胞組成的鞭毛室和身體頂端的出水口組成海綿動物特有的複雜溝道系統。



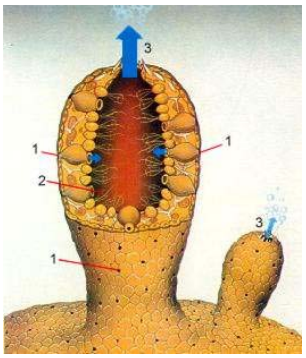
17. **海綿動物的體壁由內、外兩層細胞構成**，外層細胞扁平，內層細胞長有鞭毛，多數是有原生質領，又叫“領細胞”。在內外兩層細胞間，還有一層中膠層，其中有像變形蟲的遊離細胞（變形細胞）、生殖細胞、造骨細胞、海綿絲細胞等等。它們只有構造和機能上的差別，沒有組織分化。（請參照右圖）



18. **骨骼分兩類，一類是針狀、刺狀的鈣質或矽質小骨骼，稱為骨針；另一類是有機質成分的絲狀骨骼，稱為骨絲。**由於海綿動物的體壁內長著具有支持作用的針狀骨骼，叫做骨針。通常根據骨針的性質，可以分為鈣質海綿和非鈣質海綿兩大類。其骨針型態多變，主要分成以下類型。

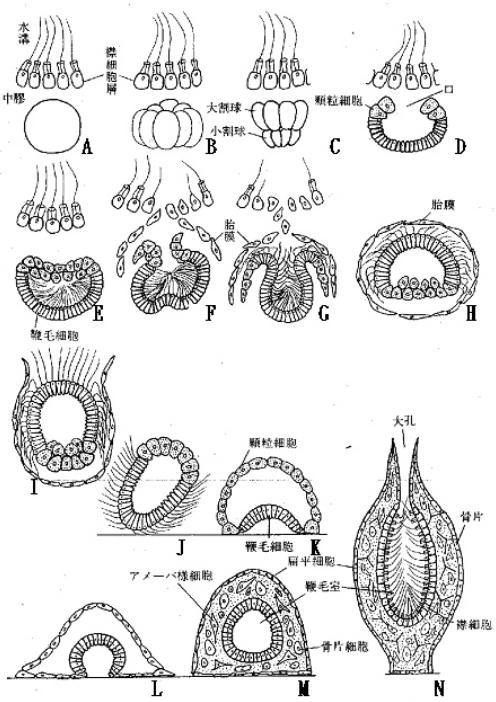


19. **海綿動物獲得食物是用一種濾食方式。海水從其四週無數細小的入水口進入，海綿利用鞭毛運動覓食水中浮游生物後，再由上方出水口排出。**（海綿動物通過不斷振動體壁的鞭毛，使含有食餌的海水不斷從這些入水孔滲入瓶腔，進入體內。接著無數的領鞭毛細胞由基部向頂端螺旋式地波動，從而產生同一方向的引力。當海水從瓶壁滲入時，水中的營養物質，如動植物碎屑、藻類、細菌等，便被領鞭毛細胞捕捉後吞噬。經過消化吸收，那些不消化的東西隨海水從出水口流出體外。）



20. 鞭毛的擺動是要耗能的。對營固著生活的海綿動物來說，從食物中獲得化學能來之不易。因此，**海綿動物總是生活在有海流經過的海底，在千百萬年的進化過程中，完善了一套利用天然流體流動能的本領，從利用海流流動產生擺動而節約了寶貴的食物化學能**。一個高 10 釐米，直徑 1 釐米的海綿，**一天內能抽海水 22.5 升**，出水口處的水流速度可達 5 米／秒。海綿動物正是有了濾食和節能的本領，才能在缺乏營養的熱帶珊瑚礁中和極地陸架區世代繁衍。

21. **海綿的生殖有無性和有性兩種。海綿一般雌雄同體，有時在同一個體上發生性逆轉**。有性生殖上，受精方式特別，精子釋出後隨水流到另一海綿內，被領細胞攫住，領細胞變為變形細胞，並把精子送到卵處。胚胎發育有不同的途徑，結果幼蟲的型式不止一種。幼蟲游泳數小時至數天後，尋找適宜的場所固著，經變態而長成新個體(右邊圖示為石灰海綿的有性生殖到成長的過程)。此外，無性生殖方式有數種，例如芽球生殖，即由細胞集聚起來形成芽球。



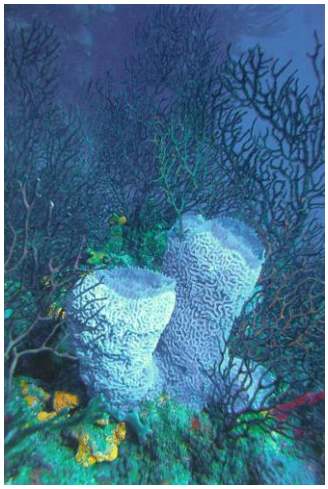
A受精卵 BC卵割期 D口胞胚期 E形成胎膜前
F~H胎膜的形成 I孵化 J附著 K~N變態

22. **海綿動物都具有非凡的再生能力**。有些海綿動物被磨成粉後再經過篩選，成了很細很細的小顆粒，卻仍然具有頑強的生命力，將它們拋進大海中以後，不但不會死去，相反每一小塊都會漸漸長大，變成了一個個新的海綿動物。有人還曾經把兩種不同顏色的海綿動物放在一起，經擠壓和細篩過濾，濾過的遊離而分散的細胞，最初相互靠近，過一段時間便分開，幫派分明地聚集、排列，在適宜的條件下，竟又不斷生長成兩個新個體。這個實驗說明瞭海綿動物的細胞雖有所分化，但仍處於低級階段。

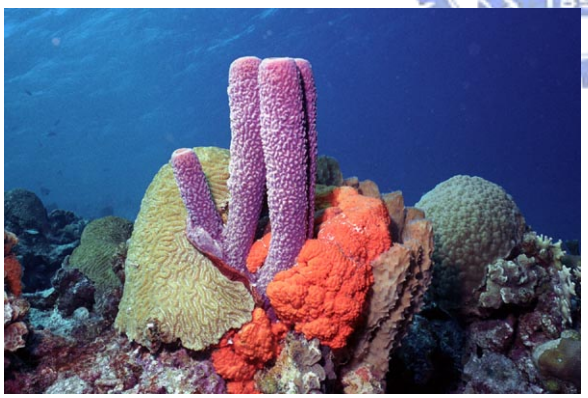
23. **海綿動物總是形單影隻地獨處一隅**，凡是海綿動物棲居的地方就很少有其他動物前去居住。科學家分析這種現象形成的原因首先是海綿動物對那些貪食的動物沒有任何吸引力，它渾身的骨針和纖維使其他動物難以下嚥，因此海綿動物的天敵不多。其次，海綿動物大多棲息在有海流流動的海底，而很多動物都難於在那樣的環境中生活。因為在那裏，它們的幼蟲或被水流沖走，或被海綿動物濾食。此外，海綿動物身上通常都有一股難聞的惡臭，這也是可能是其他動物不願與之為伍的原因之一。

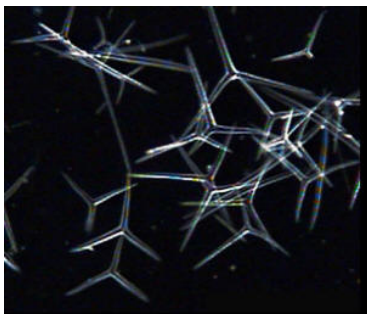
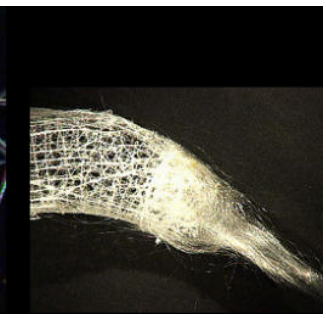
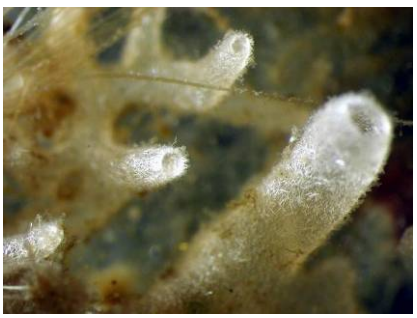
24. 儘管如此，**海綿的表面或水管和腔中也有部分小型動植物生活著，例如像”偕老同穴”的現象**，當儷蝦還是幼體時，便成雙結對地經偕老同穴的篩板孔進入海綿中空的中央腔，在那裡生活、成長，取食隨著海水流入的有機物。當儷蝦的身體逐漸增大後，由於體長超過了篩板的孔徑，就不可能再透過那些篩板孔，於是便成雙結對地永久被禁錮在偕老同穴的腔中，與偕老同穴合為一體，從而白頭到老了。

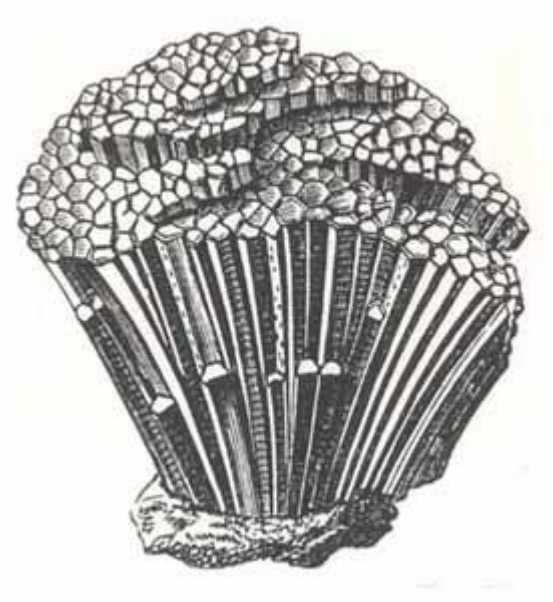
補充各類海綿圖片：







Appendix 3: Brief Interview-phase one

Problems

1.請問您如何”選擇”資料中水母的概念?
2.以及您如何”衡量”資料中水母的概念是不是你所需要的? .請問您如何將水母和您的設計目標開始做連結?
3.請簡單描述您的設計過程，如何運用水母的任何概念在”手畫的過程”中轉移成您的設計到完成?
4.您認爲傳統手畫如何幫助您做這樣聯想的設計? 請說明特色和優缺點。

Subject A

我快速看過畫線部分，主要先用圖片造形和文字快速跳過。我分成兩個部份，形式造型方面(照片)和文字本身提供水母的特色。一開始先學著描繪水母的樣子，先畫水母的型態，試圖想要找一些特殊的形式，從水母中開始發展。接著開始回應攤販的設計。 另外一方面，文字中有提到一些特性，可以拿來運用到攤販這個題目上，比如說水母有群居、三代同堂的特性。可能是八條子午管可以反射出藍色燈光，且有透明性，漲的像傘，反向噴水前進，所以想說這些是不是可以被連結到我的設計題目。從這些去下手，去邊畫邊想，邊畫長的像它的，又從畫的過程中發展出設計的可能性。後來在畫的過程中，畫到中途的時候要停下來思考一下，那到底要怎麼回應設計題目。後來是從直覺的覺得類似傘狀的構造是可以伸縮張開之類的，配合人的多寡的形式，且可以遮避風雨。所以我的設計是比較像是半室內的空間，一些線條構成的骨架，可以張開跟伸縮，甚至可以收起來。當這些攤販構成在一起時，是大大小小的，其實人的進入可以由任意方向。此外，水母還有一個特性是中間中空的構造，所以我聯想到我的攤販中間的部份可以有一個開口，這開口可以排放味道，或者是採光和風。也會垂釣一些燈光，一絲一絲亮亮的，這個東西會因應不同的環境高低來做不同的改變。

此外，做設計的時候，不能一直畫一直畫，需要停下來思考哪些東西是我要的哪些可以拿來被發展，所以最主要跳到設計時，有一個空白期需要想。但這是經由前面畫的過程中有靈光一現覺得這個東西是可以被拿來延伸成設計的平面剖面部份。

我覺得用手畫來做這種類比性的設計，我覺得一開始要很快速的從”看到的東西”用自己的手去快速描繪，可以快速了解其結構，其實這是有幫助後面的探討和發展，所以這是很直覺性的。其實他會一直被轉化，一開始長的就像原本的水母，但設計者可能幾筆就畫完覺得重要的部份，又會從這個東西聯想到其他的東西，在一直畫的過程中，慢慢累積後在一起看的時候，會看到另外的東西，才會變出設計。畫的可能是自己想到才畫出來，可能某方面少了一點天外飛來一筆的可能性。

Subject B

其實就是很快的搜尋關鍵字，挑出有具空間性的東西，像是群聚和浮游。水母的構成有水，就讓我聯想到可以運用充氣的概念來表達，群聚則是可以表達可以組合的概念，浮游代表可移動可變形的狀態。我搜尋了這些具有空間議題的關鍵自後，就開始轉化成許多草圖 diagram，也是一種設計操作方式。至於如何將水母和攤販在一起，我會先畫一個基本的攤販形式，去瞭解他有什麼性質，在和我之前畫的 diagram 不斷交錯的想。像是我就發覺攤販會有一個橫向排列的方向性，這個時候我就會試圖畫一些圈圈，看能不能把這些圈圈串連成乘一個面向性的東西，但我感覺好像很難。

總而言之我的過程一直重複著四個步驟，關鍵字畫、diagram、操作攤販繼續畫、diagram。這個過程中我一直操作群聚的概念，後來覺得水母中生長過程中往下翻和往下翻的動作，這時候已經開始打結，當群聚、往上下翻和軟的等等概念組合在一起，我已經開始打結，因爲這麼多豐富的概念卻沒辦法同時在一個平面表達出來，平面的草圖已經沒有辦法操作。後來畫到某一個的時候，我的直覺就認爲要用這一個做下去，此外做的時候我腦中會快速搜尋過去腦海中看過大量的案例。

我想透過傘，round comer 就是一個點代表一個圓的角落空間，那他基本上是可以被變形，可以藉由切線來改變剖面形狀，是散佈在地表上面。這是一個一個攤販的單元，這是由很多個圓構成，圓可以改變半徑，然後從立面看就是改變剖面。還有我爲了要拉進填充體的概念，還有水的概念，所以轉換成充氣的結構。這些 round corner 是硬的，就是一個一個攤販的單元，拉進群聚的概念，然後再加上水的概念，在塞入氣球讓他填充，因此產生內外分別，氣球內象徵內部，人可以走進攤販內部。

傳統手畫像列關鍵字，或是做一些抽象的表達，拉一些箭頭或快速畫一些表現或操作的圖。可是當遇到稍微複雜一點的就會卡住，就像我想做翻轉的東西我就是沒辦法想出來要如何表達。傳統手畫會有很多 diagram，而每一條線條都可以變成我下一個想法的來源，像我的結果就是不小心線畫重一點結果就出來，這都是意外。或是像翻轉的這個

Subject C

像我會交互的看兩邊的資料，因爲主要主題是攤販，所以我會從參考資料中找出可以被抽象成攤販的概念，或是可以跟攤販有關的連結。像資料中提到群聚的概念，發光、有百分之九十五的水，這時候我會想說，水母是百分之九十五的水，那攤販會是怎麼樣，大概是百分之九十五的空間，所以我的攤販是被空氣膨脹起來。我試著去找出一些對應，然後水母是遊移、短暫停留的，和攤販有某種程度的相似。那水母會收縮，也許也在談攤販在尺寸上因不同的應用會有收縮的狀況。資料中還有講水母有三個層次，表皮、中膠和胃皮，可以對應回攤販說胃皮是攤販服務的中間層，中膠是移動器官，可以做爲攤販移動或運動的可能，外皮是界定水母形狀的外皮，所以我想說這有沒有可能被我做爲攤販界定領域或圍塑攤販的東西。

然後我會先從一些關鍵字，攤販和水母的概念，用關鍵字的方法，先把這些條列出來，去想他們可以對應的關係。一開始很忠實的去寫水母有哪些知識性的東西，然後寫一些攤販本來就具備的特質，那到第三層

的時候，我開始把這兩個東西去做結合，去做一些詮釋上的調整，就是說也許水母的三個曾就是攤販的什麼什麼事情，他就會幫我做爲我設計的一個架構。就是關鍵字。彼此連結，形成我主要的概念。

接著後來就面對到形式的問題，水母帶來形象的感覺，要怎麼去跟我的這些概念做結合，水母是比較輕質透明的東西，可能我利用充氣的薄膜之類的去表達可充氣又可洩氣，又變動又輕質的感覺。當然還是有骨架，水母的觸角被我做爲骨架，所以我就開始畫這樣的草圖。那當然草圖之後要開始進入比較實際的部分，例如說他需要充氣，他骨架需要衝起徠，還有稱起徠後有多大的範圍，我就會想他和人的尺寸是怎麼樣。

到了最後一個階段，已經建構的差不多，所以就開始畫接近正圖的部分。那因爲中間還有想了一下水母還有群聚的關係，一開始我再講單元的東西，群聚的部分有想說有的事攤販販賣的主要部分，其他有可能是座位區或什麼，就不一定是一個一個的攤販，有可能是友的區域是一個大圓桌給人坐著，有的是服務的區域，所以從平面看會是這有大有小這樣的關係。還有水母夜間會發光，試著把他會發光的功能轉化到攤販，也許夜間會有 LED 燈會照明，如果水母是吸引獵物，那他就是吸引人潮。

另外，我覺得手畫還滿接近我的思考，因爲我用關鍵字做思考會比較沒有隔閡，寫下後又會直接轉成圖形，畫草圖的話用手畫來畫會比較沒有距離趕，因爲他可能會很草，用簡單的線條勾勒出一些想法，接下來比較正的圖我可以去描繪一些比較細膩的部分，也許看起來很隨性，但在畫的過程中我已經再不斷的理解一些東西，所以到正圖的部分可以很清楚的去描繪出來。手畫可以用看起來很草的東西，其實很多思緒已經在裡面。但是我覺得就我的東西應該會有一些不合理的部分，但是手畫看不出來，像是放開收縮的關係，但這種東西需要用 3D 去想會比較適合。這部份還有待去想他細膩的部份。

Appendix 3: Brief Interview-phase two

Problems

1.請問您如何”選擇”資料中海綿的概念?
2.以及您如何”衡量”資料中海綿的概念是不是你所需要的? .請問您如何將水母和您的設計目標開始做連結?
3.請簡單描述您的設計過程，如何運用海綿的任何概念在”手畫的過程”中轉移成您的設計到完成?
4.您認爲電腦媒材如何幫助您做這樣聯想的設計? 請說明特色和優缺點。

Subject A

海綿的概念主要也是從圖片去了解，主要是從剖面去下手，資料中有提到海棉有水孔系，所以就從他複溝型的剖面去發展。所以我一開始是從一個圓形，上面有一些開口，和一些孔隙，其實就類似複溝型這個剖面的概念，只是海綿是透過水流的功能，而我就把他轉化成空氣對流的概念，再慢慢去衍伸。接著再去了解一些海綿的型體構成，一開始也是像上次手畫這樣去試圖的表現出這東西到底長怎麼樣子，然後就開始去想怎麼構成空間。題目中表示短暫居住空間可能要具備可攜帶性和便利性，所以我想了一個結構的方式，就是充氣。那他裡面的構成有骨架的部份，也有充氣的部份，骨架的部份是引伸海綿擁有的針狀的骨骼的概念，並且也有海綿的纖毛的概念，所以做了一些示意性的孔隙，會有一些開口。孔隙是在外面，中間是有採光的透明玻璃，再來有骨架，再進去有充氣的氣墊。整個是可以變形的，回應到海綿可以透過不同的環境和水流變形的概念。因爲他是原生動物，有非凡的再生能力，就算磨成粉也可以在長起來，不斷的複製和適應不同的環境，就類似我的設計中可以由小變大且適應不同環境的居住空間。

其實因應每個人的設計方式不同，過程也會有所不同。在這兩次的實驗當中，我都用同一種方式在思考，並挑戰不同的媒材是不是都可以做出來。後來我覺得即使在數位媒材的環境中，一樣也可以做出來，只是你要對這套工具夠熟悉。像手畫的時候也是很直接的模擬他，電腦中也是一樣發生這個過程。但這裡面有一些不一樣的地方，像手畫是在一直畫一直畫的過程中會找到一些可能性可以被發展，然而電腦不一樣，是因爲他有多元的指令，像說你可能會畫到一半試試某個指令去發展看看，或者想說自己會的功能有哪些，所以一開始是想像朝那個方向去發展，但是當你真正在用不同的指令時可能又會發現許多新奇的點。因此，電腦媒材比起傳統手畫媒材帶了更多可能性，因爲手畫是依照自己畫的結果衍伸，電腦卻因爲多元的指令參數而有更豐富的發展。但是必須要澄清一點是，電腦媒材會花更多的時間，因爲在操作各種指令的同時，必須用不同的參數去 study，而去達到自己最想要的結果。只是電腦媒材的限制性，會在於不同的軟體會有不同的限制性，每種電腦軟體的特色不同，有的擅長建立自由曲面，有的擅長折版，然而手畫也同樣有限制在，這因應每個設計者的設計習慣。其實最主要還是設計者的大腦和思考。

Subject B

一開始一樣是尋找關鍵字，很快的把所要運用的概念和關鍵字簡單的打下來並建立在腦海中，從資料上瞭解海綿是一種類群，而且是簡單的原生動物，就想像是簡單細胞可以被不斷複製的關係。而且很重要的是水管系的概念，其中複溝型的剖面是可以引起我注意的。其他像是其構造中內外皮層，等等相關的關係也被我去放在腦海中。

一開始我做一個單元，這個單元是依照上面的概念所提示的，那每個單元就是一個居住單元，利用像是可以水流進去的水管的關係去做運用。我先用做簡單的正方形狀再讓他變成自由曲面，然後經由編輯這些曲面的關係，好處是這樣可以被隨意的拉升，而且隨意的連接，並產生內外皮層的關係，我可以很自由的去變化我想要的海綿的形式和關係。而這些參數和操作模式是我過去已經非常熟悉的慣用手法。

後來我開始旋轉複製這個單元，這種關係就像海綿本身的單細胞重複的構造關係，像這樣旋轉一圈，複製完後在單元彼此的路徑間建立關係，相互連結起來，做好了以後再對上下兩層再做一次，不斷的堆疊在進行操作，中間是空的，像是複溝型剖面中空的感覺。這就是像是海綿一個洞一個孔隙中的那種關係的運用。

因爲這是一個住宅的集合體，利用海綿水管系的關係作串連，就像是另一種形式的集合住宅的概念。他的單元去反應水管系這件事情，就是開孔的部分，希望能外連到內，內連到外，中間並沒有樓板，一塊一塊組織慢慢衍生。

我用電腦媒材的操作性很強，可以直接在電腦上進行試驗，像皮層如何翻轉、開孔，或互相怎麼樣接，這樣非常的方便，又很快速，完成度也很高。手繪的話操作性就很弱，上次進行實驗我就卡在操作的部分而沒辦法很順利的繼續進行下去。但是手繪的話可以集合比較多的概念，但是他的想法會比較抽象一點，電腦就會很精確的表現出來。電腦的優勢在於可以容易被操作，很容易的對設計形式或是機能或尺寸的操作，電腦都有更大的優勢。

Subject C

一樣抓到一些關鍵字，海綿是跟著流速還有波浪會產生不同的形狀、且會晃動、還有單溝型的海綿型態，因爲我覺得他的東西有辦法和我之後要做的物理採光有關。還有上方出水溝排出這種概念等等，這些概念其實和我單元式的住宅有關係，所以我就抓了這些東西當我的 keywords。

其實主要像我剛講到他會隨著波浪的這件事，這個部分我會想到住宅可能要有陽光和通風的關係，而這是很單溝型的設計，所以上方有採光，氣流也可以從這裡排出，這個是在回應單溝型這個簡單的想法。流速和可以晃動這東西，這個設計可以隨著不同的時間和季節移動，然後他中間有個軸，樓板是水平的，這個開口會根據時間的差異而改變，像是說中午要避掉陽光，會比較測一邊，而且也會隨季節而改變，因爲台灣的緯度會隨著季節而不同，這就是利用軸的關係去移動和改變。所以我是滿簡單的實踐實現幾個概念，單溝型和上方出水口，上面是休息的部份，下面是廁所或小客廳。型態上滿直接的對應。

對於這個形體上，我覺得的用這個工具(sketch up)的話，其實不知道是幫助還限制，它讓我決定會是這樣子，我用我擅長的軟體是沒辦法做出我心裡想的形，所以我把他匯進我比較不擅長的軟體最處理，又有更多限制。因爲時間的關係，和軟體本身的限制，造成我很快速直接的對應形體的相似度，而沒有比較深入的對應一些實質的關係，這可能是個問題。好像是因爲把這個邊界畫的比較強烈一點，所以就把這兩個元素分開來，那就才會突然想充氣可以分到旁邊，最後的圖才會出現。

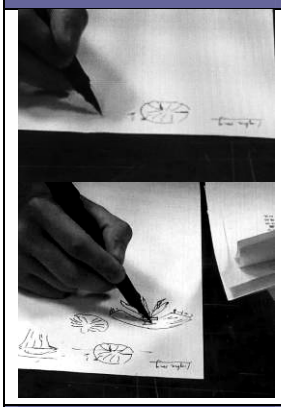
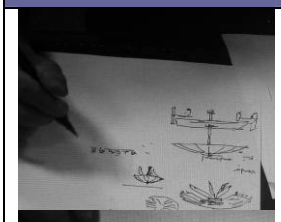
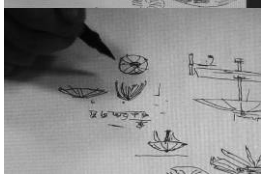
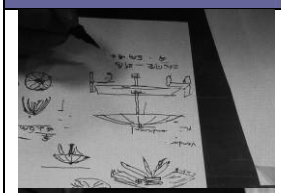
可以，可是因爲是因爲時間的限制、還有我本身不熟析電腦環境的關係，就像我在手繪過程中，我可以很直覺的寫字，但是用電腦打關鍵字，可能打一打選錯字還要做修正，這型爲間接讓我的思考中斷，同樣的問題對應到我在軟體中建模的過程。要嘛就是我不熟悉，要嘛就是時間上不足夠，說不定這些指令就是那麼繁瑣。另外，例如我用筆畫畫一個剖面，其實很快的草草幾筆就可以帶過，因爲他比較曖昧，但在電腦中，因爲太精準了，如果有一點缺損我可能就會要去修正，所以就會花很多時間在這些動作上，而真正的想法就忽略了。手繪的會比較多曖昧和想像，用電腦媒材，明明是同一個階段的過程，會少掉許多曖昧的關係，所以會比較直接的呈現結果。而軟體中如何保留曖昧的 concept 的概念很重要，而我目前沒辦法用熟悉的軟體做出這種曖昧的過程。但我有看過一些比較藝術性的 3D 圖有呈現我感覺到的 concept。

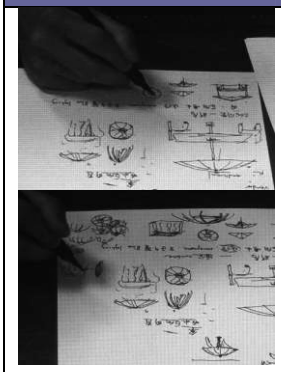
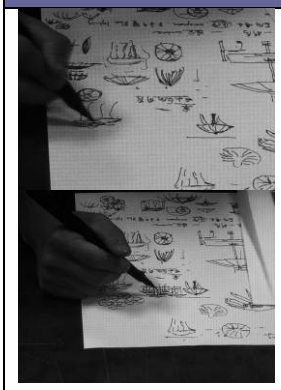
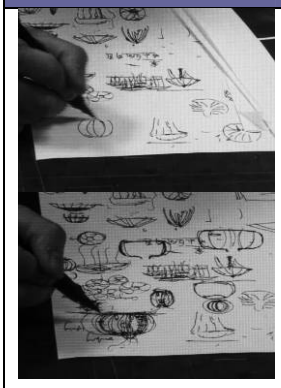
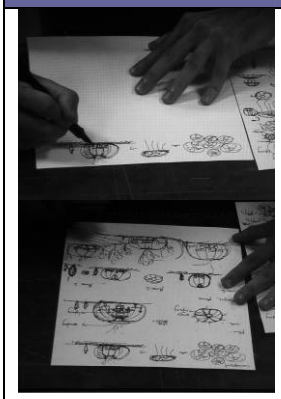
但軟體會比較在講空間的關係，可以比較有效幫助你理解空間的關係和尺寸。如果對於比較複雜的模型會更有幫助。

其實我兩次的思考過程滿類似的，都是找一個關鍵字然後去想要怎麼連結。其實我兩次的思考模式都一樣，只是呈現的部分的會導致不同型態的發生。

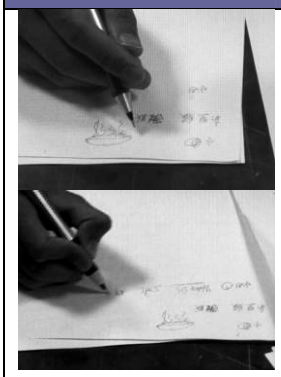
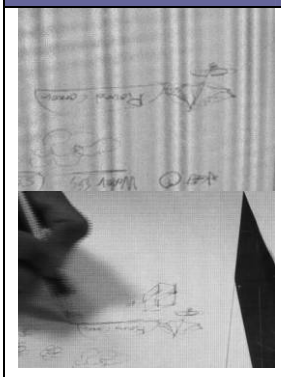
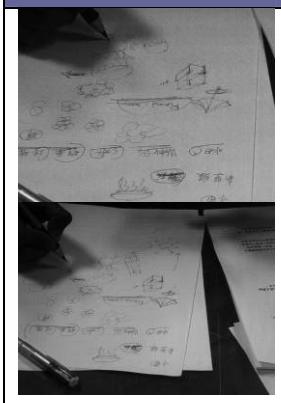
Appendix 4: Coding results

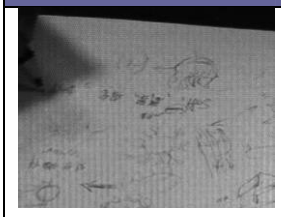
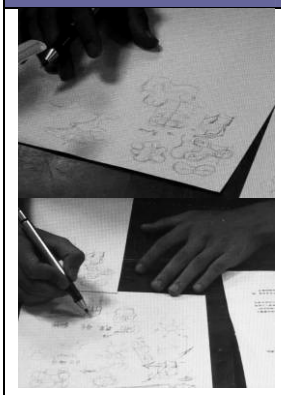
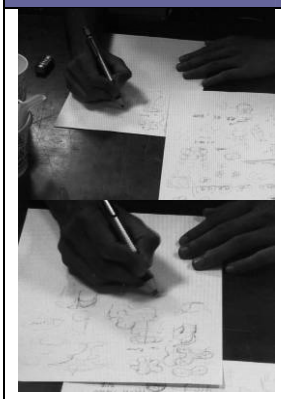
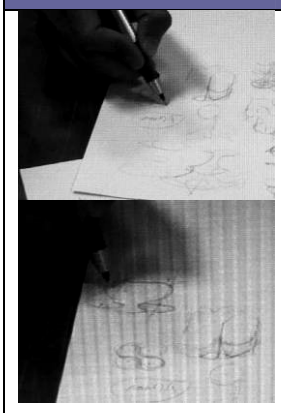
Subject A（Experiment phase one）

Visual Data	Time & Clarification	Coding Scheme
	0:00-7:00	
	先從構想來源資料中選擇一些圖面去模仿，手畫水母的模樣，邊畫邊想可能性。	**S** **M** **E** **L** **R** ■
	＊受測者在這階段已先閱讀構想來源資料，他先把一些他有興趣的關鍵字先記到腦海裡。	**P** **F** **Fu** **Str**
	7:01-8:00	
	開始想要嘗試將水母和傘聯想在一起，因而繪製傘狀的結構。	**S** **M** **E** **L** **R** ■
		P **F** **Fu** **Str**
	8:01-12:00	
 	寫下水母的特性關鍵字「噴水反向前進」，接著開始畫幾張草圖。	**S** **M** **E** **L** **R** ■ ■
		P **F** **Fu** **Str**
	12:01-14:00	
 	又再抓到幾個關鍵字，並寫下來。	**S** **M** **E** **L** **R** ■
	1.三代同堂代表群居，也意味組合。 2.傘 3.反向噴水 4.水分，透明。 5.八子五管(水母發光的來源)	**P** **F** **Fu** **Str**

	14:01-23:00	
	畫一些傳統攤販的草圖，再畫水母造型草圖，嘗試要把目標和來源結合。	**S** / **M** / **E** / **L** / **R** ■
		P / **F** / **Fu** / **Str**
	23:01-27:00	
	開始藉由水母觸角和群聚的造型，邊畫邊開始引發出一些想法。	**S** / **M** / **E** / **L** / **R** ■
		P / **F** / **Fu** / **Str**
	27:01-35:00	
	畫最終的概念圖。	**S** / **M** / **E** / **L** / **R** ■
	1.八條子午管光線轉換成藍色光源(A,P)。 2.八條子午管的水母觸角轉化成線條形的骨架，可以伸縮和張開，或甚至收起來，引用於水母身體的縮收伸張的關係(HR, Str/Fu)。 3.伸縮張開的形式配合不同的攤販形式，並大大小小產生群聚關係(三代同堂特性)(R,P)。 4.外型上的對應(A,F)。	**P** / **F** / **Fu** / **Str** **2** / **1** / **1** / **1**
	35:01-50:00	
	畫一張補充設計構造和設計結果的詳細概念。	**S** / **M** / **E** / **L** / **R** ■
	1.水母中空的特性類比設計圖中空的構造，其供排放味道以及光源有空氣流動(R,Fu)。 2.水母三層結構對應設計中的服務空間關係(HR,Fu)。	**P** / **F** / **Fu** / **Str** **0** / **0** / **2** / **0**

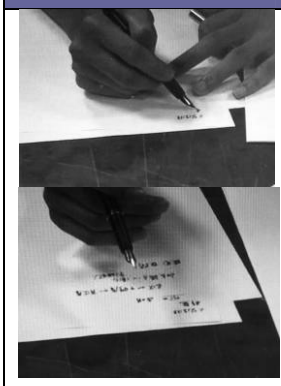
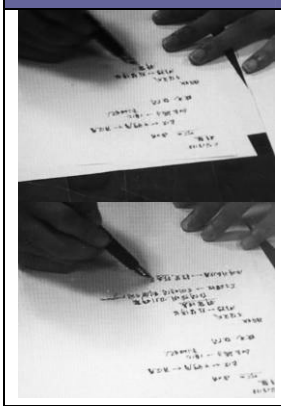
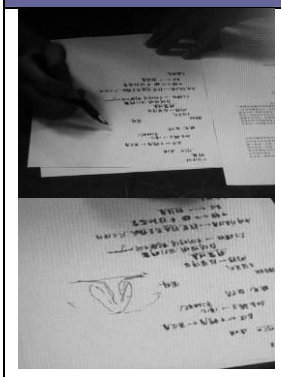
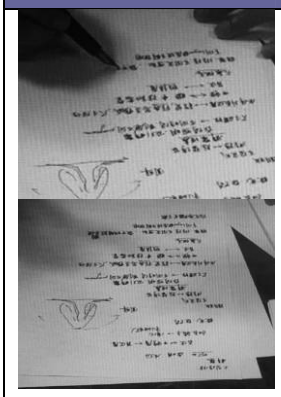
Subject B（Experiment phase one）

Visual Data	Time & Clarification	Coding Scheme
	0:00-4:00	
	受測者將資料中具有可能性的關鍵字寫出來，並且和設計目標作連結。並簡單的畫一個草圖。	**S** ■ **M** ■ **E** **L** **R**
	1.浮游意味爲可變形 2.群聚意味可以被組合 3.水意味可以被充氣	**P** **F** **Fu** **Str**
	4:01-7:00	
	接著畫傳統攤販的形式，包含傘狀結構以及平行排列的攤販。	**S** **M** ■ **E** **L** **R**
	＊受測者認爲平行排列的攤販是具有方向性。	**P** **F** **Fu** **Str**
	7:01-10:00	
	接著將所畫的傳統攤販和水母嘗試做連結，不斷的畫許多草圖。	**S** **M** ■ **E** **L** **R**
		P **F** **Fu** **Str**
	10:01-16:00	
	嘗試將水母的群聚和傳統攤販面向性做連結，繼續畫著許多草圖。並將圓的概念放入其中。	**S** **M** ■ **E** **L** **R**
	1.水母以圓的概念做表達(A, F)	**P** **F** **1** **Fu** **Str**

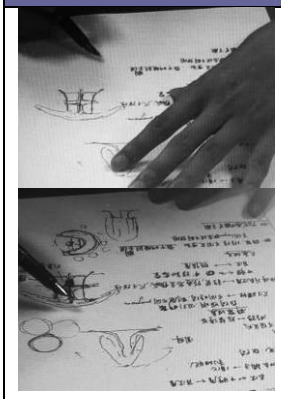
	16:01-17:00	
	停止畫草圖，再將關鍵字重新寫一次。多了一個翻轉的概念。	**S** **M** **E** **L** **R** ■
	1.軟質的 2.群聚 3.組合 4.翻轉（引伸至水母生長史外形的翻轉）	**P** **F** **Fu** **Str**
	17:01-23:00	
	開始操作翻轉的可能性，但發現很難處理，到最後衡量之下放棄了這個想法。	**S** **M** **E** **L** **R** ■
		P **F** **Fu** **Str**
	23:01-33:00	
	繼續不斷的畫草圖去引發想法。	**S** **M** **E** **L** **R** ■
		P **F** **Fu** **Str**
	33:01-36:00	
	在畫到其中一個草圖時，概念圖就被決定出來了。	**S** **M** **E** **L** **R** ■
	1.一個一個攤販聚集在一起，象徵水母群聚的意涵(R, P)。 2. 水母水的概念轉變成充氣的結構(A, Fu)。 3.外表是硬的結構，內部塞入氣球填充，因此產生內外分別，像是水母的構造層次(R,Str)。	**P** **F** **Fu** **Str** **1** **1** **1**

	36:01-42:00	
	最後補充一些機構和概念。	**S** **M** **E** **L** **R** ■
	1 像水母身體伸縮變形的概念，這個圓的瓣販空間是可以藉由切線來改變剖面形狀，並散佈在地表上(HR,F/Str)。	**P** **F** **Fu** **Str** **1** **1**

Subject C（Experiment phase one）

Visual Data	Time & Clarification	Coding Scheme
	0:00-5:00	
	從來源資料中找尋關鍵字	**S** **M** **E** **L** **R** ■
	他寫下含有百分之九十五的水 透明, 水母有三個層，細長觸手，消化用的刺細胞，and 發光。	**P** **F** **Fu** **Str**
	5:01-12:00	
	受測者開始去用文字簡易的表達攤販的機能，也是用一些簡易的關鍵字表達。在寫這些文字同時，也和水母的概念開始做連結。	**S** **M** **E** **L** **R** ■
	1.不固定 2.水母遊移>攤販短暫停留 3.群聚現象 4.夜間照明吸引群聚 5.尺寸彈性,不同時間有不同的 program 6.水母三層結構對應攤販不同的機能 7.水母水分轉移成充氣縮放概念 8.外型	**P** **F** **Fu** **Str**
	12:01-13:00	
	在做連結的同時也簡略的畫了一個水母外型的草圖。	**S** **M** **E** **L** **R** ■
		P **F** **Fu** **Str**
	13:01-17:00	
	繼續將構想來源和設計目標作連結。	**S** **M** **E** **L** **R** ■
	再寫一次概念，包含群聚、游移、不固定、變動，夜間明顯被辨識，不同的 layout 的不同的使用。	**P** **F** **Fu** **Str**

17:01-25:00



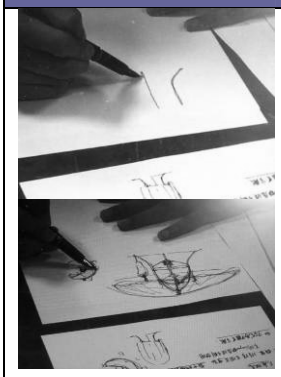
當文字連結進行完畢後，確定一些功能的對映關係，開始用草圖去操作，一邊畫一邊對映連結一邊想設計目標的結構。

S	M	E	L	R
	■		■	

草圖中畫了一些比較機能性的概念，包含加LED，打氣，和簡單的縮放的圖面。
1.水母水分轉移成充氣縮放概念(A, Fu)
2.夜間照明吸引群聚(A,P)
3.尺寸彈性,不同時間有不同的program(R,Fu)

P	F	Fu	Str
1		2	

25:01-30:00



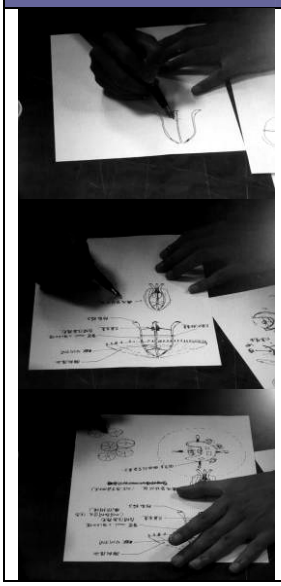
開始畫最後的圖面的草圖。

S	M	E	L	R
			■	

其中顯示人和設計目標的關係。
1. 外型(A,F)

P	F	Fu	Str
	1		

30:01-46:00



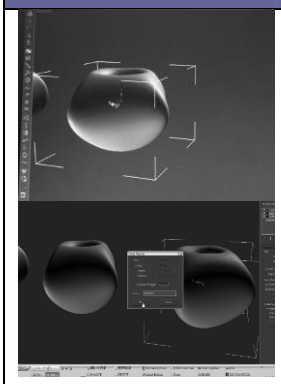
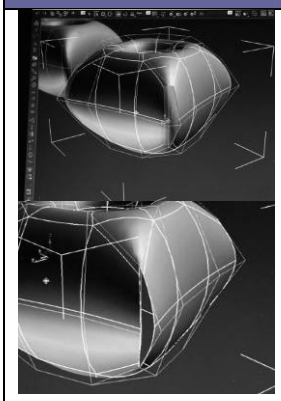
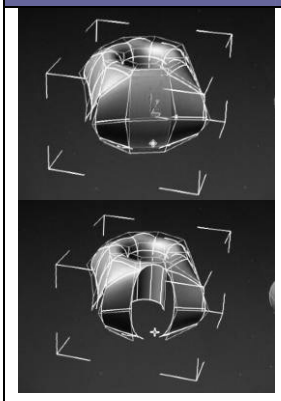
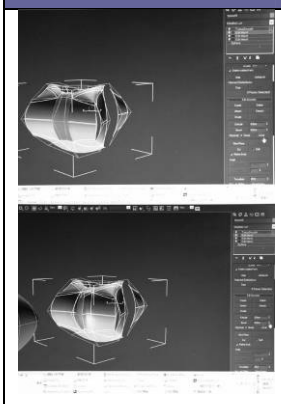
再畫另外一張去補充說明設計成果的機能和構造。

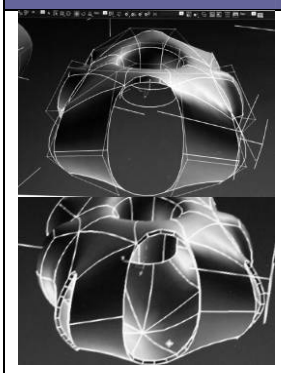
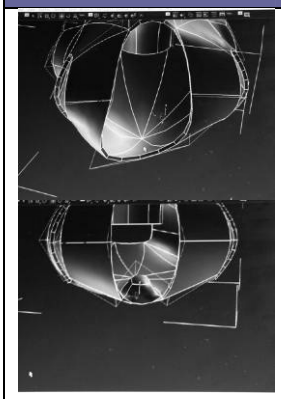
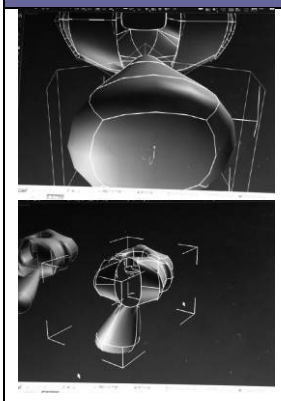
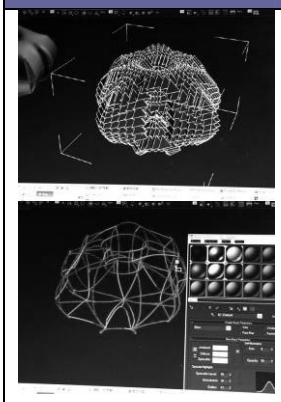
S	M	E	L	R
			■	■

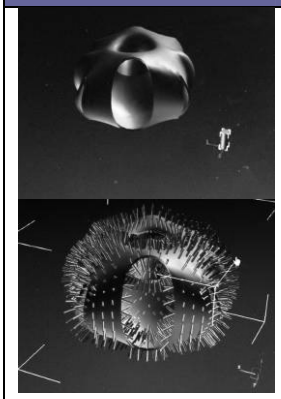
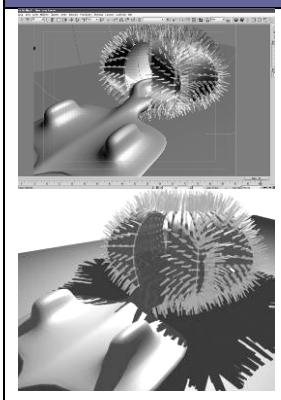
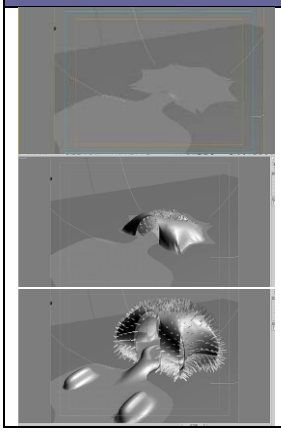
表達了機能結構的關係。
其中包含:
1.水母觸角引伸骨架系統(A,Str)。
2.充氣傘狀結構中有檔雨和收納的功能(Fu)。
3.下方有充氣馬達(Fu)。
4. 水母遊移>攤販短暫停留,不固定(A,P)
5.移動輪子對應水母的移動(A,Fu)。
6.座位和服務區的關係>對應群聚(R,P)。
7.水母三層構造對應不同攤販的服務機能(HR,Fu)。

P	F	Fu	Str
2		4	1

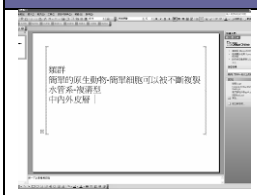
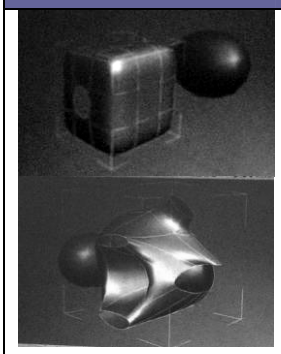
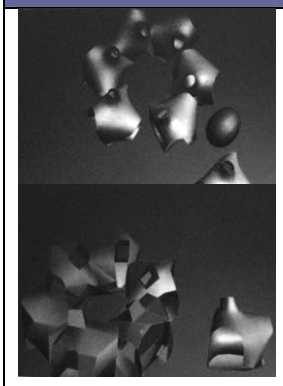
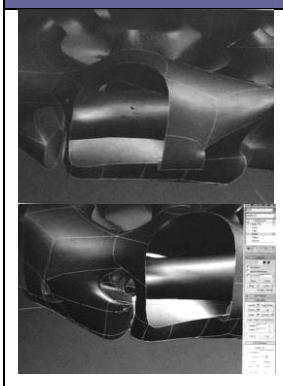
Subject A（Experiment phase two）

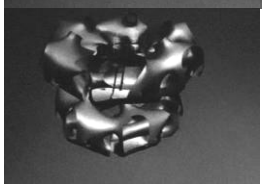
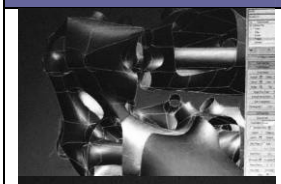
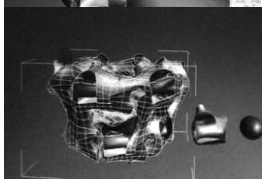
Visual Data	Time & Clarification	Coding Scheme
	0:00-5:00	
	閱讀完資料後，便馬上進入 3Ds Max 系統，建立一個圓形量體中間有個孔洞。並複製許多相同的。	**S** **M** **E** **L** **R** ■ ■
	先從資料擷取海綿水管系複溝型的概念，接著開始就資料圖片中外型的部分開始模仿，先是建立一個圓中間中空。 1.海綿外型的模仿(A, F)。	**P** **F** **Fu** **Str** **1**
	5:01-8:00	
	對這個物件挖洞。	**S** **M** **E** **L** **R** ■ ■
	1.海綿會被水流通過，轉化成透過氣流通過(A,P)。 2.多孔系的關係概念去開孔(R, Fu)。	**P** **F** **Fu** **Str** **1** **1**
	8:01-10:00	
	Wadong again.	**S** **M** **E** **L** **R** ■
	1.多孔系的關係概念去開孔(R, Fu)(上面已探討過)。	**P** **F** **Fu** **Str**
	10:01-12:00	
	藉由參數的關係，去尋找合適的型態。	**S** **M** **E** **L** **R** ■
		P **F** **Fu** **Str**

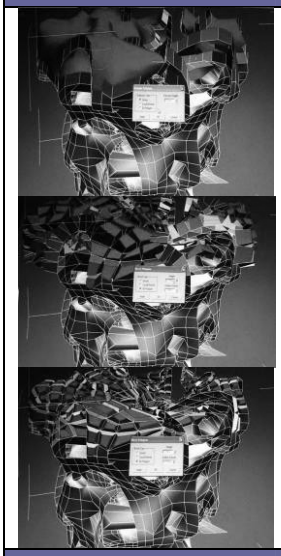
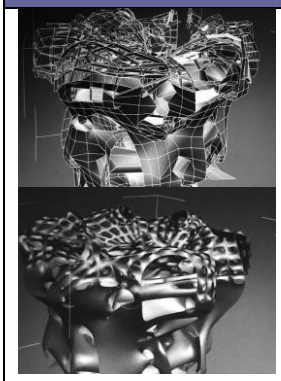
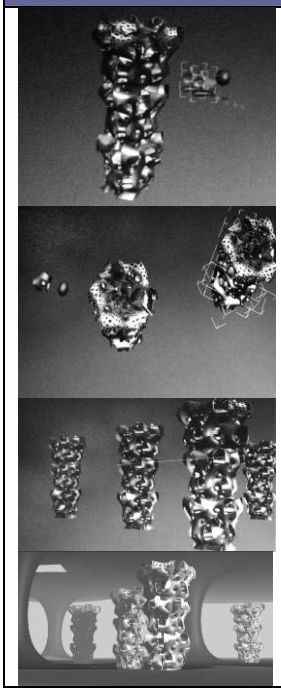
	12:01-16:00	
	建立厚度的部份。	**S** **M** **E** **L** **R** ■
	1.海綿的不同層次有厚度(A,P)。	**P** **F** **Fu** **Str** **1**
	16:01-21:00	
	藉由參數的改變以嘗試不同的型態的可能性。	**S** **M** **E** **L** **R** ■
		P **F** **Fu** **Str**
	21:01-27:00	
	建立入口空間的部分。	**S** **M** **E** **L** **R** ■
		P **F** **Fu** **Str**
	27:01-32:00	
	建立骨架的部分。	**S** **M** **E** **L** **R** ■
	1.骨架的部份是引伸海綿擁有的骨骼用來支撐關係的概念(R, Fu)。	**P** **F** **Fu** **Str** **1**

	32:01-39:00	
	建立凸狀的骨架部分。	**S** **M** **E** **L** **R** ■
	1.象徵海綿骨骼的其中一種，骨針(R, Str)。 2.內部的微凸部份則象徵纖毛的部份(A, Str)。	**P** **F** **Fu** **Str** **2**
	39:01-45:00	
	將各層合併後，處理色彩的部分。	**S** **M** **E** **L** **R** ■
	1. 骨骼、皮層、纖毛的關係象徵海綿構造的關係(HR, Fu/Str)。	**P** **F** **Fu** **Str** **1** **1**
	45:01-59:00	
	建立動畫。	**S** **M** **E** **L** **R** ■ ■
	1.可變形的關係象徵海綿可透過不同的環境和水流而變形的概念(R, Fu)。 2.引用海綿的再生能力，就算磨成粉也可以再長起來(A, Fu)。	**P** **F** **Fu** **Str** **2**

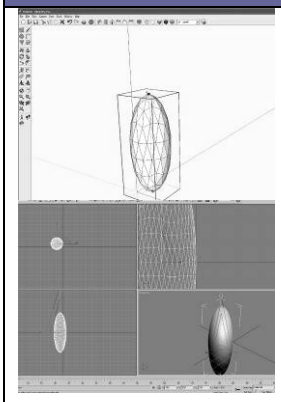
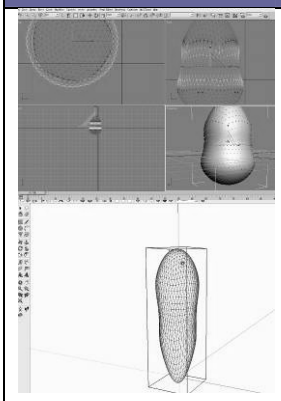
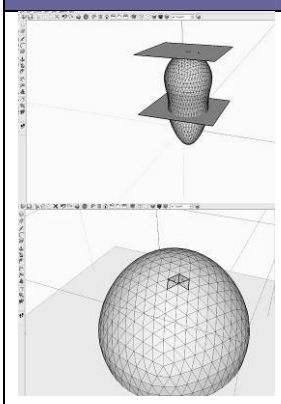
Subject B（Experiment phase two）

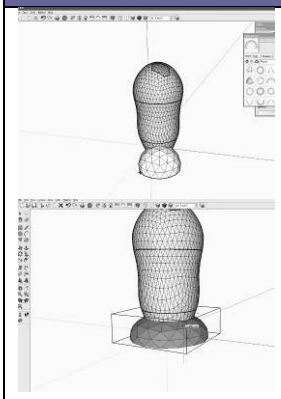
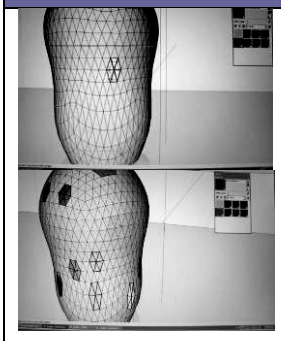
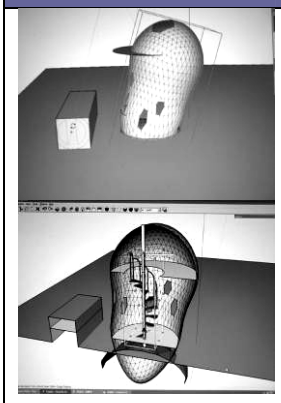
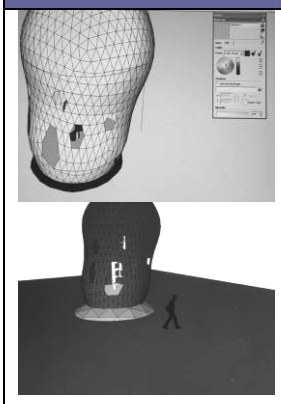
Visual Data	Time & Clarification	Coding Scheme
	0:00-3:00	
	從資料中找尋可用的關鍵字並寫下來，並思考如何建立連結。	**S** ■ **M** ■ **E** **L** **R**
	1.類群 2.簡單的原生動物- 簡單細胞可以被不斷複製的概念 3.水管系-複溝型 4.中內外皮層	**P** **F** **Fu** **Str**
	3:01-8:00	
	進入 3Ds Max 系統中，一開始設法找尋適合的形狀去建立單元。	**S** **M** ■ **E** **L** ■ **R**
	建立海綿單細胞水孔隙單元部份。 1.類比海綿單細胞(A, P)和有水管系的概念(R, Fu)，並建立一個單元。	**P** **F** **Fu** **1** **Str** **1**
	8:01-10:00	
	將單元圓形排列複製。	**S** **M** **E** **L** ■ **R**
	1.類比海綿本身單細胞不斷重複的關係（R, P）。 2.類比海綿有點圓的感覺的外型（A, F）。	**P** **1** **F** **1** **Fu** **Str**
	10:01-15:00	
	處裡單元間彼此連接的部份。	**S** **M** **E** **L** **R** ■
		P **F** **Fu** **Str**

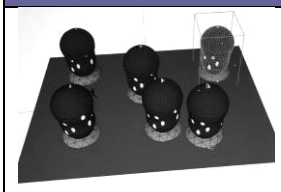
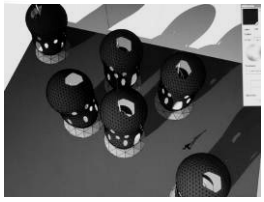
	15:01-19:00	
	再將單元縱向複製。	**S** **M** **E** **L** **R** ■
	2.類比海綿有點圓桶的感覺的外型（A, F）。 2.類比海綿複溝型剖面中空並對外有複雜的孔隙連結的關係(HR, Fu)。	**P** **F** **Fu** **Str** **1** **1**
	19:01-23:00	
	處理細部連結的部份。	**S** **M** **E** **L** **R** ■
		**P** **F** **Fu** **Str**
	23:01-28:00	
	處理下方延伸的部分。	**S** **M** **E** **L** **R** ■
		**P** **F** **Fu** **Str**
	28:01-30:00	
	再度複製成長條。	**S** **M** **E** **L** **R** ■
	1.模仿海綿長條狀的外觀(A, F)。 2.結構上根據海綿的關係，無樓板，而是運用孔隙間的內外皮層關係去衍生而成(HR, Str)。	**P** **F** **Fu** **Str** **1** **1**

	30:01-36:00	
	處理上方開孔的部份，並嘗試了非常多種參數。	**S** | **M** | **E** | **L** | **R** ■
		P | **F** | **Fu** | **Str**
	36:01-41:00	
	決定好確定的上方開孔的外形。	**S** | **M** | **E** | **L** | **R** ■
		P | **F** | **Fu** | **Str**
	41:01-60:00	
	做最後的處理，複製好幾個量體，並處理細部和基地圖。 1. 轉化海綿群聚的關係(R,P)。	**S** | **M** | **E** | **L** | **R** ■ ■
		P | **F** | **Fu** | **Str** **1**

Subject C（Experiment phase two）

Visual Data	Time & Clarification	Coding Scheme
	0:00-3:00	
	邊看資料邊打下關鍵字。	**S** **M** **E** **L** **R** ■ ■
	1.水管系單溝型的剖面（採光） 2.波浪、流速會產生不同的形狀和晃動 3.上方出水口	**P** **F** **Fu** **Str**
	3:01-11:00	
	先匯入 Sketch up 軟體後，發現不容易操作出想像的型，便再又匯入 3Ds Max，不斷的嘗試。	**S** **M** **E** **L** **R** ■ ■
	1. 以單溝型爲概念，嘗試找一個適合的造型(A,F)。	**P** **F** **Fu** **Str** **1**
	11:01-13:00	
	確定造型後，編輯曲面的部分讓他有曲度。並再匯入受測者比較熟悉的 Sketch Up。	**S** **M** **E** **L** **R** ■
	1.轉化海綿有點曲的外型(A,F)。	**P** **F** **Fu** **Str** **1**
	13:01-17:00	
	處理樓板的部分，以及對上面層挖洞。	**S** **M** **E** **L** **R** ■
	1. 轉化海綿上方出水孔的水流關係爲通風採光的概念(R, Fu)。	**P** **F** **Fu** **Str** **1**

	17:01-22:00	
	設計下方基座的部分。	**S** | **M** | **E** | **L** | **R** | | | ■ |
	1. 轉化海綿下方爲基底，穩定上部空間的結構概念(R, Str)	**P** | **F** | **Fu** | **Str** | | | **1**
	22:01-29:00	
	周圍挖許多小洞	**S** | **M** | **E** | **L** | **R** | | | ■ |
	1. 轉化海綿入水孔小洞的概念，讓小洞和大洞產生空氣對流關係(R,Fu)	**P** | **F** | **Fu** | **Str** | | **1** |
	29:01-36:00	
	產生位移的關係，並處理中間樑柱和樓梯的部分。	**S** | **M** | **E** | **L** | **R** | | | ■ | ■
	1. 透過基底和樑柱的支撐，其會和海綿一樣因爲不同的風向和力道而位移和旋轉(HR, Fu/Str)。	**P** | **F** | **Fu** | **Str** | | | **1**
	36:01-46:00	
	處理色彩和尺度的部分。	**S** | **M** | **E** | **L** | **R** | | | | ■
		P | **F** | **Fu** | **Str** | | |

<table>
<tr><td></td><td>46:01-52:00</td><td colspan="5"></td></tr>
<tr><td rowspan="4"> 
  </td><td>複製。</td><td>S</td><td>M</td><td>E</td><td>L</td><td>R</td></tr>
<tr><td rowspan="3">1.轉化海綿群聚的關係(R, P)。</td><td></td><td></td><td></td><td>■</td><td>■</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>P</td><td>F</td><td>Fu</td><td>Str</td><td></td></tr>
<tr><td>1</td><td></td><td></td><td></td><td></td></tr>
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