THE EARLY PRODUCT CONCEPT PROTOTYPING STRATEGY IN PARTICIPATORY DESIGN PROCESS

LEE YU HIN BRIAN

PhD

The Hong Kong Polytechnic University

2019

The Hong Kong Polytechnic University

School of Design

The Early Product Concept Prototyping Strategy in Participatory Design Process

LEE Yu Hin Brian

A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy

January 2019

CERTIFICATE OF ORIGINALITY

I hereby declare that this thesis is my own work and that, to the best of my knowledge and belief, it reproduces no material previously published or written, nor material that has been accepted for the award of any other degree or diploma, except where due acknowledgement has been made in the text.

_____________________________ (Signed)

LEE Yu Hin Brian (Name of student)

Abstract

Helping design workshop participants to envision or create a prototype, whether visual or physical, is not without obstacles for many experienced workshop organisers. I am frequently invited to host different types of design workshops for diverse participants. My reflections and those of other workshop facilitators express the same frustration: it is always difficult to help diverse participants to create a prototype and move forward their concept for the public or for user evaluation. This thesis investigates the early design process and seeks to understand how and under what conditions we can enhance the prototyping ability (prototype-ability) of participants from different backgrounds in a collaborative workshop setting based on 12 cases and a conceptualisation test for a large group of people. The results are compared with the framework for organising participatory design tools and techniques, suggesting an extension of the framework to improve the effective early prototyping process.

To respond to the call for collective action to foster a liveable and smart city in global and local contexts, with characteristics such as limited resources, population ageing and pollution, a better articulated participatory design approach is needed to effectively engage diverse stakeholders and multidisciplinary experts. In Manzini words (2015), we need to visualise the contexts and improve the facilitation of social conversation about the future. This thesis investigates the design process in a participatory design workshop environment and aims to inform a practical methodology for the early phase of the design concept development process – the description of a facilitator training framework that can guide participants to formulate an appropriate verbal and visual concept (or rough sketches) for the development of the early phase product concept prototype (also called proof-of-concept prototype) that can ensure explicit conversation amongst the stakeholders. How can we ensure an effective prototyping process in the early phase of the design workshop? This is considered the most critical question for participants to meet the criteria and guidelines for prototype-ability in the collaborative product design process.

The main research objective of this thesis is to identify the relationship between quality interaction in the prototyping process and appropriate design outcomes, in which any

factor may improve the initial design concept generation phase. How can the quality of early phase concept prototyping be improved in a collaborative design environment? This question is often asked in design workshops by participants who cannot effectively create an appropriate and articulated prototype in a teamwork environment, and facilitators are rarely able to provide a good answer. Ownership of the project by the participants is also essential for participatory design to carry through and sustain the work, even if the workshop facilitators and design team leave the project. Thus, a prototype is a stepping stone in a participatory design project.

The initial discussion of the work focuses on understanding design activities, design thinking and design reasoning, particularly visual and spatial thinking. The following scaffolding work is a discussion of the design process and quality of the design workshop work for and with stakeholders. Twelve workshop cases involving designers and non-designers were selected for the case study analysis. The main problems of the design workshops are identified and the problem space, focusing on the prototyping process, is the main research target. The case studies revealed that quality prototyping was one of the most influential factors for successful workshops. The concepts associated with the elements were identified during the case studies. For instance, the transformation of an abstract idea into a concrete concept (concreteness), the situational design (situatedness) and the physicality of the design concept (objectness) were the three main hypothetical factors of the design experiment of this research. Design-trained and non-design-trained informants were invited to perform sequential design tasks, including concept brainstorming and scenario design through sketching. The final discussion correlates the performance of the informants with the factors enabling concept representation that affect prototyping.

In the last section of the thesis, I construct a descriptive model to articulate the parameters to improve early phase product design concept prototyping through qualitative and quantitative studies using case studies, interviews and a design task.

Publications Arising from the Thesis

Peer reviewed journal:

Lee, Y. H. B. (accepted, 2019). Prototyping – The dual actions. *The Cubic Journal.*

Peer reviewed conferences:

Lee, Y. H. B., Chan, L. H., & Tang, M. X. (2013). Park seating furniture design in Hong Kong: A case study of inclusive design and its relation to user interaction. *Include 2013*, Hong Kong, 2-3 July 2013, HK.

Lee, B., Leong, B., & Chan, G. (2015). A reflection on designing participatory design workshop – Case study of elderly product development workshop with multidisciplinary collaboration. *DesignEd Asia 2015*, Hong Kong, 1-2 December 2015.

Acknowledgements

My deepest gratitude goes to the two people who have influenced my PhD studies the most: my supervisor, Professor Kin Wai Michael SIU, and my former supervisor, Professor Ming Xi TANG. I am immensely grateful to Professor Tang for giving me the opportunity to pursue my research in the area of design thinking. His innovative theory of the development of product form was enlightening. Without Professor Siu's expertise in design research and education, my thesis would not have been improved. He provided valuable insights that consistently guided my study and contributed significantly to my research.

I would like to acknowledge Professor Timothy Joseph JACHNA, Dr. Yan Chi Jackie KWOK, Dr Man Wah Eva YUEN, Mr Ding Benny LEONG, Mr. King Chung SIU, Dr. Ka Nin Kenny CHOW, and other colleagues in the School of Design for their inspirational discussions of the philosophy of design education, which helped to shape my initial PhD proposal or shed light on my career in design research. And I would like to send my greatest appreciation to my mentor Mr. Chiu Kwong CHIU who enlightened me with his exceptional insights on the design and culture during my early years in design school.

My thanks go to The Hong Kong Polytechnic University for supporting the development of staff to study for the PhD degree. I would also like to thank the professors, research students and all professional administrative staff in the School of Design, Research Office and Human Resources Office of the Hong Kong Polytechnic University for their support. My thanks also go to all of the workshop organisers, facilitators, helpers and participants who supported and inspired me in my workshop planning, facilitation and evaluation.

I would like to thank Professor Johannes Ferdinand Hoorn, Chair of the Board of Examiners, and Prof. Renke HE and Dr Miaosen GONG, my External Examiners, for their constructive comments and suggestions on my work.

Finally, my deepest thanks go to my wife Lap Hang CHAN, our newborn Kin Ching LEE, our parents and all of our family members. Their selfless love and encouragement helped me to complete my PhD studies.

Yu Hin Brian Lee
June 2019, Hong Kong

Table of Contents

List of Figures

List of Tables

Chapter 1 Introduction

Learning by doing is a prominent approach. It goes hand in hand with a design development strategy that incorporates empathy, participatory design and iterative design to enable innovative, user-centred design. A prototype, as the artefact produced by learners, provides an opportunity for collaborative learning while working together. It is essential to ensure seamless conceptual exchange and collaborative prototyping to formulate and develop an effective design strategy or innovative solution to tackle more complex social innovation challenges. Most design workshop practitioners recognise the positive role of prototyping as a catalyst for the design process. Unfortunately, prototyping guidelines are well below expectations and there is a lack of studies on the causes of unsuccessful prototyping and what strategies can improve the process. Therefore, this research work investigates the collaborative design platform, using unique real cases of different product and service design workshops for and with stakeholders (or workshop participants) as the main source of data, contributing to the theoretical discussion on prototyping ability (prototype-ability) and how it can be enhanced in the participatory design process.

Prototyping is a type of learning approach. This study assumes that subject prototyping is an experiential learning technique, in relation either to the mastery of traditional craftsmanship or the development of digital technology-driven product design, which can be elucidated by the pedagogical approach underlying Seymour Papert's constructionism, itself based on Jean Piaget's epistemological theory of constructivism. In contrast with the traditional passive learning approach, such as lectures, this learning theory emphasises individual learning by making things in the education environment and the processes by which learners actively build their unique systems of knowledge and self-directed learning while engaging in conversation or interaction with artefacts.

Among the different types of design workshops addressing different challenges, a social innovation project is a platform that aims to develop objective and systematic design solutions to a complex system, such as a design project connected to social and economic networks. For instance, The Park Lab was conducted between April and September 2017 by the Jockey Club Make a Difference Social Lab, which was the first community-initiated public service innovation lab in Hong Kong to improve public park design through community participation, design thinking and co-creation (Binder & Brandt, 2008) with prototyping. The project team included community stakeholders, citizens, public servants and designers. The discussion and exploration of project work involved different layers of concepts, including stakeholder needs and concerns and environmental, administrative and educational issues. The Park Lab is discussed later as one of the case studies (www.mad.asia/programmes/mad-social-lab/93).

Among various complex design tasks, one of the principal approaches of this type of design platform is to encourage participants to empathise, identify, analyse, integrate and prototype, engaging end users and other stakeholders in carrying out interventions, feedback collection or evaluation. The participants may not be trained designers or equipped with appropriate design thinking skills, such as skills in sketching, storyboard illustration and model making (from simple mock-ups to high fidelity models). It is reasonable to assume that the participants (especially those who are not trained in design) do not know how to communicate or explore creative concepts with other people and with constraints. They may need additional support. Therefore, it is essential to have an applicable theory to guide workshop facilitators to evaluate and give appropriate instructions to participants. However, there is a lack of formal discussion of and strategies for facilitating co-prototyping. Different people have different working or thinking styles, which may also affect the effectiveness and outcomes of the co-creation platform.

In general, prototyping is an essential workshop component used to address various social innovation issues. It is a tool that helps individual learners make sense of their experience of complex situations in the context of designing public goods or meeting community needs with other participants. Based on my observational study of various design workshops with different combinations of participants from different professions and backgrounds, there is a critical problem: individual learners or designers (workshop participants) are often unable to create an appropriate prototype at an early stage. In some extreme cases, the organisers need to hire professional designers to participate in concept representation and the prototyping process. As a result, first, the workshop is behind schedule, which may affect the outcomes if participants cannot produce an appropriate prototype. Indeed, some workshops only run for one day or even three hours. Second, well-trained participants may dominate the group's voice and people with weak visualisation and/or modelling skills may be suppressed during the concept generation stage in a group. Although facilitators manage teams in different ways, for instance, preparing materials to improve prototyping, establishing rules to avoid dominant players and encouraging weaker participants to evaluate the prototype after its creation, their participation at the early stage may diminish ownership in the group project, which is the basic principle of participatory design.

The study aims to identify and construct a descriptive theory to explain the factors and correlations affecting one of the most frequently used design processes – early phase prototyping (transforming design concepts from text into visual ideas (scenario design)) from the perspective of constructionism (prototyping as a learning process) and visual reasoning (the main factor that may affect prototyping performance). The results enabled the development of a participatory design approach, advancing the prototyping method to envision and explore complex scenario studies that benefit user experiences and interactions and service and product design.

Why is the focus on transforming textual elements into visual elements and not the other way around? Or why not study different types of cognitive tools, such as mathematics, music or kinaesthetics? I show that the majority of workshop facilitators and participants use text as the dominant language for communication and recording. For instance, a Post-it is a favourite tool for capturing ideas and supporting concept clustering activities. Although sketches and collages of relevant images can also be introduced, my experience is that few participants use sketches or other non-textual means. People can write down their ideas quickly. Conversely, drawing a concrete concept or scenario takes time and requires specific skills. Therefore, this research also explores how abstractness and concreteness affect prototyping performance.

1.1 Context and justification of the study

Tonkinwise (2011) argued that the current dominant perspective on design thinking (design research) is limited to the discourse of design-based innovation and management research. He pointed out that this only reflects some of the knowledge of design thinking and that the academic world should also embrace the cognitive processes of design activities: anything to do with form-giving, pleasant appearances and the feel of a design. These concerns are related to the generation or representation of a design concept.

This chapter discusses the importance of understanding issues related to the prototyping process of product design concepts (one of the outcomes of form-giving) in a collaborative environment. Different types of product design work involve prototyping. Only work related to product design with a social innovation mission can cover various categories of design outcomes: (i) stand-alone products, such as upcycled products (e.g. a lamp made from recycled PET bottles or home furniture co-created with and for marginalised people); (ii) stand-alone products connected to environmental design, such as public outdoor product design (e.g. park and public furniture design); and (iii) product and service systems, such as bicycle rental business or sustainable farm products for end-user networks.

Due to the nature of the participatory approach, such projects face challenges. For example, it is important to ensure that non-professionals can contribute to the professional and sophisticated social and economic problem space or take ownership in a bottom-up strategy. Another challenge lies in accommodating the different voices of people with diverse backgrounds and values.

Due to the complexity of the problem space, this research only focused on the early phase of concept development or representation, in which I identified one of the significant challenges to hosting participatory design workshops: the performance of concept prototyping. When hosting different design workshops for people from diverse backgrounds, I found that the performance of the participants varied. If someone formulated an appropriate concept prototype (sketch or mock-up) earlier, his/her team was better able to build and evaluate the concept.

Political issues or concerns always play a critical role in the power of the participants and the execution of a community project, design projects related to the power structure of the community, society or an organisation. As proposed by Ezio Manzini (2015), 'collaborative encounters' is the purpose of the act of design for social innovation whereby the collaboration of people lies the centre of the action in which the actors are involved to imagine new possible outcomes with sensibility and creativity. Collaborative work brings benefit or called shared value to the individual who encounters the others and exchange something such as time, care, experiences, expertise etc. Thus, the core of collaboration is the encounter where two or more people interact with working out something in which they recognised the value. Therefore, the essential measurement of successful early phase concept prototyping is the **value exchange in the collaboration environment**. Furthermore, he emphasised that the first concern to ensure an active, collaborative, sustainable design project is to make the project's context visible. Some questions are prior to asking before knowing how the workshop participants interpret the state of things and what the opportunities could be recognised. He argued that the first and foremost questions are 'how can we **make sense of the complexity of the present and the dynamics** that stir it? How can we **make viewpoints and wishes explicit**? How can we **imagine what doesn't exist but could?**' (Manzini, 2015, p.121).

What is early phase concept or proof-of-concept, and where does it occur?

Designers or participants in design workshops co-create a new understanding of the problems and/or creative solutions to overcome the limitations of different design opportunities and constraints. In general, a design workshop is constituted by stakeholders who play the role of designers. Based on the Stanford d.school design thinking process, the diagram below illustrates different operations, empathy, concept definition, ideation and prototype stages, with the exception of the testing stage and the iterative process (Figure 1.1). It represents the basic unit of a general design process. In general, especially for short design workshops (e.g. from three hours to three days), the iterative process is limited, thus a useful method is needed. This research examined the **first loop of the design process** (**from empathy to prototype**). Therefore, the study focused on the **early phase prototype or proof-of-concept prototype** (e.g. sketches, scenario design drawing or a simple mock-up), which will be used interchangeably in this thesis. It is the opposite of the high fidelity model which is often developed later in the design project. Furthermore, the user or public engagement is essential to promote bottom-up empowerment and ownership in the participatory design process, as is prototype evaluation or testing to facilitate people's participation, connect people's feedback and stimulate creative ideas or dialogue. It is essential to understand and explain the correlation between the designer's or the participant's experience and the successful transformation from concept (ideate stage) to early phase prototype (prototype stage).

Based on a review of many workshop design materials, formal discussion of and methods supporting ideate-to-prototype actions are insufficient. In current practice, there are many more sophisticated methods that we can adapt from other fields. Interviews and observational research methods from the social sciences or anthropology can be used for the 'empathise' stage, and theories to frame or cluster phenomena and concepts can be taken from the social sciences or other scientific disciplines for the 'define' stage. There are also many cognitive tools to facilitate concept or insight development for the 'ideate' stage, such as the 'activities, environments, interactions, objects, users' (AEIOU) and peoples, objects, environments, messages, services (POEMs) frameworks. Unfortunately, concept/scenario prototyping methods have rarely been discussed. This research was based on the premise that earlier prototyping will more quickly lead to more successful design. This argument is discussed in more detail in the following chapters.

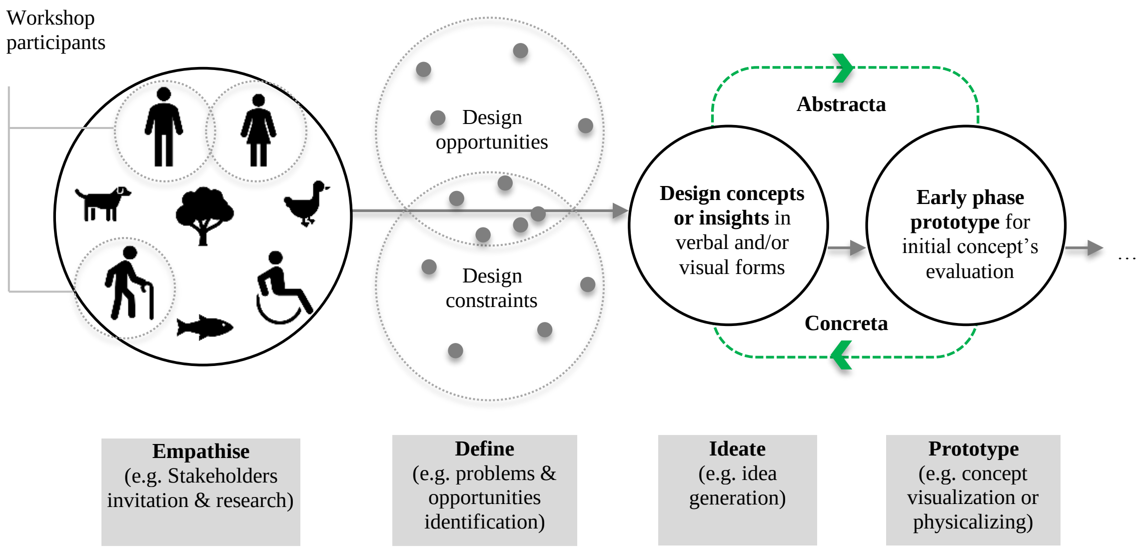


Figure 1.1 Concept diagram illustrating the basic unit of a general design process incorporated into a standard design workshop with multiple stakeholders. The 'Test' stage is excluded.

Figure 1.2 A selected recording of the Park Lab design workshop – Post-it notes were used to capture the participants' individual needs or ideas during the brainstorming session on the first day of the workshop. Almost all of the concepts were explained in text.

Figure 1.3 Concept sharing after individual brainstorming and display of all Post-it notes. Photo of the Knowledge of Design Week Elderly Design Workshop in 2017 organised by the Hong Kong Design Centre and the Helen Hamlyn Centre for Design, Royal College of Art.

The integration of ideas (or concepts) represents the learning experience of individuals or a group of participants (assuming that they are all engaged in the discussion).

<u>Scenario design (prototype) is one of the ways of moving forward</u>

There is another approach to brainstorming ideas or concepts, as used during the Knowledge of Design Week (KODW) presented below. The facilitator motivated the participants to select a potential concept and organise it under a certain theme with a timeline. For instance, this case focused on the emotional experience of older people in an elderly care centre on a particular day. This action offered a method of managing and identifying specific information after a Post-it brainstorming session in a group. This method was based on the perceptions of the participants rather than the actual experiences or reflections of real stakeholders (the elderly living in the care centre). This is **a type of scenario prototype** that requires detailed elaboration or assumptions and has a more concrete meaning than verbal concepts written on Post-it notes.

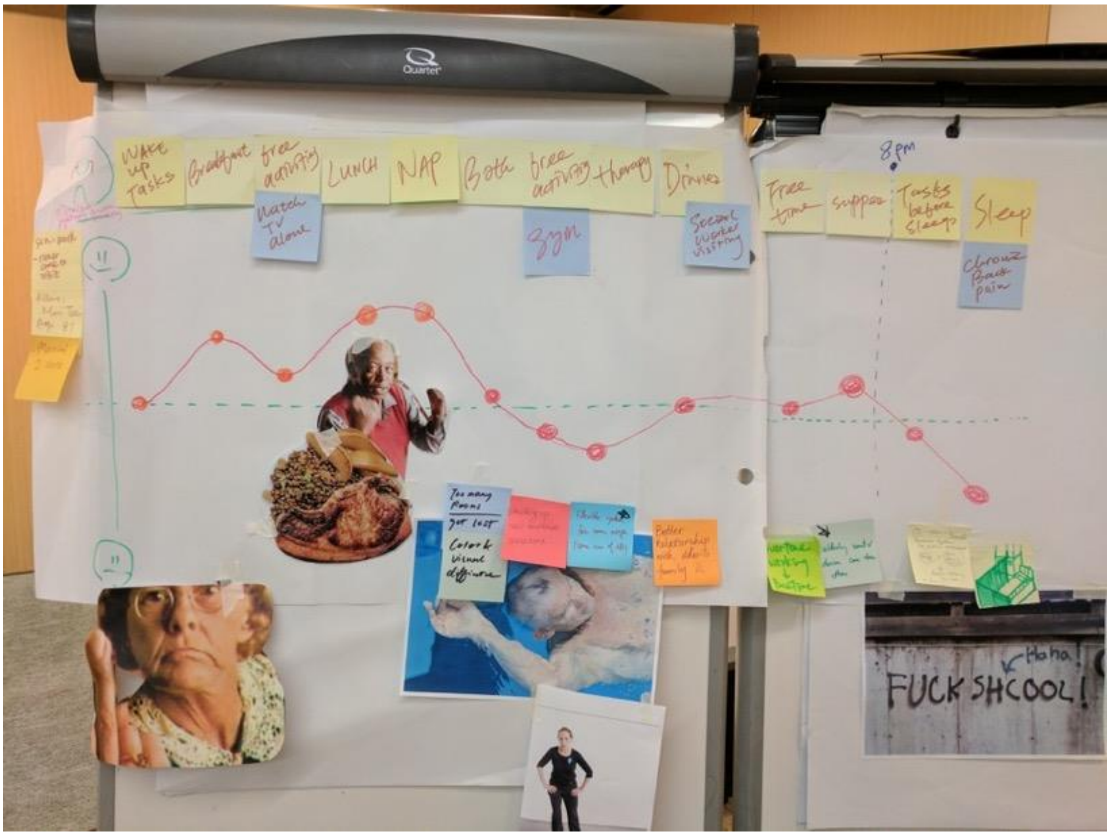


Figure 1.4 Reframing a Post-it note concept into a hypothetical user journey or experience. This is one of the approaches to managing and identifying new information based on the group’s idea brainstorming work.

What is the definition of an **appropriate prototype**? How can appropriate prototyping be better facilitated to support effective knowledge transfer, engagement and product development? What factors affect the quality of prototyping?

Moreover, participatory design involving various stakeholders requires advanced design thinking techniques and tools to enable effective communication and collaboration. Thus, this thesis used this perspective to focus on the prototyping process as undertaken by various participants. It analysed what happens and how it happens during the early stage of concept representation, without taking into account the other stages.

1.1.1 Understanding design (knowledge building in design)

1.1.1.1 Overview of design thinking research and why 'prototyping' and 'sketching' are important

Design is about looking for better solutions for the future. As Simon wrote about the science of design, 'everyone designs who devises courses of action aimed at changing existing situations into preferred ones' (1996, p. 111).

Nigel Cross argued that design is a coherent discipline of study (1982, p.1) in a Royal College of Art report entitled *Design in General Education*. The report concluded that design is an activity focused on the conception and realisation of new things. Design encompasses the appreciation of 'material culture' and the application of 'the arts of planning, inventing, making and doing'. The core of design is the 'language' of 'modelling'. In addition, design has its own 'things to know, ways of knowing them, and ways of finding out about them'. Cross compared other study phenomena across different cultures, focusing on science, humanities and design, as shown below.

Table 1.1 Comparison of study phenomena in science, humanities and design.

	Science	Humanities	Design
Phenomenon of study in each culture	Natural world	Human experience	Artificial world
Appropriate methods in each culture	Controlled experiment, classification, analysis	Analogy, metaphor, evaluation	Modelling, pattern-formation, synthesis
Values of each culture	Objectivity, rationality, and concern for 'truth'	Subjectivity, imagination, commitment, and concern for 'justice'	Practicality, ingenuity, and concern for 'appropriateness'

Although it is clear that the design process always involves multidisciplinary concerns and methods, the interwoven nature of design is driven by the designer's intention to synthesise all elements to formulate an appropriate solution abductively. The ultimate goal is a pragmatic way of **'making', the creation of a meaningful physical form**.

The **prototyping approach** (Brandt, 2007) is important for the development and improvement of **tangible experiences** in the creative process of the artificial world.

In addition, Cross (1999b) emphasised the importance of **sketching** in design based on Davies' reflection written in 1985. Davies wrote, 'I draw something – even if it's "potty" – the act of drawing seems to clarify my thoughts'. From this line, we can understand the key idea that designers adopt sketching as a tool for clarification. Clarification may involve the following.

i) **Knowing what it is**: having a clear picture of a proposed idea (relationship between the part and the whole).
ii) **Knowing how it is made**: understanding the details of the form, material, colour and texture that will be implemented in the concept and anticipating how it can be made.
iii) **Knowing how it aligns with the brief and requirements**: adapting and comparing the design criteria, including user, society, market and environmental needs.

It is also important to note that sketching is a useful **stimulus for developing ideas for creating forms**. Cross (1999a) explained this with reference to the sketches of the architect Alvar Aalto. Sketching helps designers 'see plans, elevations, sections, details, all being drawn together and thus all being thought about, reasoned about, all together, alongside calculations of areas, volumes, and perhaps costs'.

Here Cross used the term **'reason'**. He further cited Lawson's discussion of the use of sketches as a tool for criticism and discovery. Designers perceive these two actions as a critical and reflective dialogue between themselves and the sketches in an iterative process that facilitates decision-making to explore new ideas and eliminate ideas.

Therefore, this thesis focused primarily on the practice of product design. In particular, the main research interest lay in analysing **how designers formulate (argue/reason) prototypes to make sense of a design or concept**.

To better understand prototyping, there are three broad categories in the field of design research, as suggested by Nigel Cross (2006):

i) **Design epistemology**: the study of designerly ways of knowing.
ii) **Design praxiology/praxeology**: the study of design practices and processes.
iii) **Design phenomenology**: the study of the form and configuration of artefacts.

Visual reasoning is a matter of creativity in prototyping. The form of reasoning (e.g. reasoning in physics) is a fundamental marker of the epistemology of a knowledge domain or field of study. Mathematical reasoning can be clearly expressed in written form (potentially as a mathematical/numerical formula). Unfortunately, the process and design outcomes (e.g. creating a personal experience) of product development are **difficult to describe only in written or similar forms; they require visual images, symbols or even physical/tangible structures**.

To study how designers create a prototype, it is also necessary to understand the **visual and spatial reasoning** of human beings. Due to the creative nature of prototyping, design scientists find it fascinating, and cognitive scientists and computer scientists pay considerable attention to it, especially with regard to thinking patterns and processes. During the workshop and forum on Visual and Spatial Reasoning for Design Creativity organised in 2010 and the articles presented at the same time, a group of multidisciplinary design scientists addressed design issues based on the idea that design is **an activity in which the creation of worlds takes place** (Gero, 2014). The **interaction between the mind and the representations of artefacts produced by designers** attracted much attention from scientists in different domains. The forum emphasised that visual and spatial reasoning play a pivotal role in design creativity, which has rarely been discussed in the past. In addition, it was evident that designers had largely adopted the **system of external symbols** in their creations through **sketches, diagrams, visualisation and visual imagery** involving a strong commitment to visual and spatial reasoning. The discussions focused on the field of systems design (Gero, 2014).

Visual and spatial reasoning in design creativity involves external and internal representations. Most research on sketching and visual reasoning has emphasised the importance of sketching (the external form of representation by designers), paying little attention to the reasoning capability of designers in their minds (inner representation). The main problem is that this type of data (imagery in the minds of designers) cannot be seen and recorded by others. Non-visual thinkers may also find such reasoning difficult.

A holistic understanding of how designers think, and particularly how they conceive an idea or concept in any form or pattern, such as a prototype, is essential to build domain knowledge that can contribute to curriculum design for designers and the development of tools and strategies for design education and design management.

1.1.1.2 Prototyping as a type of reasoning in the product design process

From industrialisation to the emerging need for social innovation, the study of the nature of design thinking and how it can be understood and applied has become increasingly important. Although the concepts, domain knowledge and education curriculum of product design have been developed and expanded over the years, **skills in drawing, creating models or prototypes and experience design processes** (from general to specific) still play a major role in basic training in design school. A **prototype** can be considered as an ideation technique. Decision-making takes place when a physical object is built and encourages the generation of new ideas: **we build to think**.

<u>Definition of 'prototype'</u>

According to the etymology of 'prototype' from the Merriam-Webster dictionary (prototype, n.d.), the prefix ***prot-***, or ***proto-***, comes from the Greek, meaning 'first in time' or 'first formed'. A prototype can refer to someone or something that serves as a model or inspiration. It can be understood as the original model of something, considered as a pattern (or archetype). It can also refer to an individual with the essential characteristics of a later type. Furthermore, a prototype is the standard for a typical example and can be a first full-scale and generally functional form of the new type or design of a construction.

'Concept' refers to the mental ideas and knowledge that an individual possesses. Thus, a product prototype can be the first functional form of a product design concept that represents the essential features or a pattern serving as a model or inducing an original inspiration. A prototype can be further recognised through the lens of prototype theory, which describes the categorisation mode with a gradual difference in cognition. Some members of a category play a more dominant or central role than others. For instance, in the concept of seating furniture, a chair is more frequently cited than a stool. The concept or word greatly affects communication, as people may associate the abstract concept (e.g. furniture) with its different subcategories. In contrast, a prototype represents a relatively concrete type or image of the construction of the concept and induces the association of a clear and precise sensory experience, including sight (a specific type of structure, colour or symbol) and touch (a specific material or texture).

In product design, prototyping involves materialising a concept or, conversely, conceptualising an idea, by manipulating tangible materials to create a visual, physical, tactile or symbolic experience. Walsh et al. (1992) stated that design is the activity in which physical form is given to an idea or need, and it further develops from a solution concepts to a design with the specific configuration or arrangement of elements, materials and components. **The ability to shape forms (form-giving)** is an essential means of solving design problems that carries the representation of the aesthetic and functional meanings of a design. To establish the **professionalism of the design discipline**, it is necessary to construct its philosophical position in terms of reasoning, like other professions. For instance, the domain knowledge of mechanical engineering or accounting heavily relies on mathematical reasoning. Prototyping (including design thinking), a process considered tacit and implicit, is an innovative activity and an effective approach to solving ill-defined problems. To better understand prototyping, it is necessary to study the **characteristics and modes of reasoning in the prototyping process**.

Much design research has focused on the **user-centred perspective**, which is useful for informing design strategy and management. Discussions about design thinking (design-specific cognitive activities), such as **the way of thinking of designers**, have also produced fruitful results. Unique ways of thinking, such as abductive reasoning, solution-oriented thinking, synthesis-driven thinking and non-linear iterative thinking to help solve wicked problems, have been considered as critical modes of thinking during a design activity.

In addition, prototyping is a method of design reasoning that goes hand in hand with the process of tackling wicked problems.

A saturated and appropriate product design solution heavily relies on how designers frame problems by proposing a product form or visual structure: its relationship with the user's or the stakeholder's experience, technologies (traditional craftsmanship and advanced manufacturing techniques), business models, the environment and societal issues. This can be inferred from the fact that designers spend most of their time sketching and/or building a physical and/or virtual prototype during the conceptualisation process. However, **little research** has focused on the visual-spatial reasoning process for conceptualising a prototype, in particular the **visual form shaping ability of designers** and the way **designers transform verbal means into visual means** as a reasoning method.

Visual-spatial thinking is related to people's intelligence. People with higher visual thinking intelligence are more sensitive to visual and spatial clues, helping them excel in reasoning in terms of visual structures and spatial relationships. Training in visual-spatial thinking is obviously the most rigorous form of training provided by most studio-based training design schools. In addition, design is an activity associated with the ability to draw beautiful objects (shaping appearance or form-/style-giving), which is an important task for industrial and product designers. Raymond Rowey (1893-1986), renowned for his prominent role in shaping the material culture and style of his time, was an iconic industrial designer of the modern design period, regarded as the father of industrial design.

A concept sketch is the most basic form of a design prototype. This reminds me of a famous 13th century story. One of the greatest masters of the early Renaissance, the Italian painter and architect Giotto di Bondone, drew a perfect circle by freehand in red paint to prove his supreme ability in painting in front of the Pope. For Giotto, this skill was metonymic of the ability of the designer. His ingenuity, closely linked with his outstanding eye-hand coordination (perceived as a natural gift by the public), could be observed in its external form (i.e. seen). Design education today still pushes students (especially at the junior level) to master sketching, although efforts have been made to switch to computer visualisation. Sketching is still considered one of the most fundamental targets of training and a practical tool for design activities.

However, not everyone who draws well is a good designer. Indeed, various design tools, such as computer software and 3D printing technologies, can be used, and may even be more powerful than traditional visualisation and hand tools. Therefore, why is sketching so important to designers? A lot of research has focused on sketching. Researchers have tried to understand the logic of concept representation for designers (or architects), enabling them to build a formal language system to optimise computer tools that can facilitate or stimulate design activities. However, there is a gap in knowledge between the design process and the visual reasoning of product designers. Designers use a creative process that combines explicit reasoning (e.g. through sketching) and implicit reasoning (happening in their minds). It is obvious that the complexity of the design experience is not fully reflected in sketches or verbal expressions. The complete phenomenon (the design experience) is a complex mixture of the embodied experience of vision, sketching (eye-hand coordination), memory, etc. Many scholars have investigated the phenomenon through in-depth qualitative studies (Goldschmidt, 2001; Gero, 2015; Owens, 2015). However, based on a **collaborative design approach with different stakeholders,** including people with no professional training on these specific design tools, conventional concept representation means that verbal descriptions and sketches on paper remain the most common tools. I discuss this topic further in the following chapters.

1.1.1.3 Development of product design research and bottleneck

This section highlights the importance of product design research and the research gaps.

From a product-centred approach to a user-centred approach to a participatory design approach

The history of product design and product designers started with the beginning of industrialisation in the early 19th century, which emerged to meet the new demands created by huge population growth in the Western world: a new division of labour and new professional perspectives, standardisation and changes in value, a new factory system and new lifestyle (vs. farming), steam engine and other new travel experiences, mass production and a capitalist hierarchy. From the era of the product-centred approach to the user-centred approach of the 1980s, it is useful to differentiate the tasks of product designers, product engineers and others in the development, manufacturing and distribution of new products, to identify unique product design knowledge and designers' contributions.

For instance, the table below illustrates the relationship between tasks and participants during a typical product design project. To simplify the iterative nature of each project, only four distinct phases and one evaluation phase are used to provide insights into the commonalities and differences between projects in the initial discussion. The descriptions reflect my personal professional practice as the chief designer of a project from 2000 to 2012. The table shows that a single actor can have multiple roles, especially the designer or project manager. In addition, individual actors can assume the roles of others and/or contribute to specific disciplinary tasks from time to time. The four classifications of actors are not bound to an individual person. Instead, they refer to disciplinary tasks. This complexity of working patterns reflects the reality of the multidisciplinary nature of product development.

Table 1.2 A case study illustrating the roles of different actors in a design process.

		Actor roles			
Project phases		Designer	Businessman	Engineer	Manufacturer
1	Discover	i. Generate design hypotheses; ii. Competitor study; iii. User study; iv. Identify possible mechanisms and production processes; v. Pricing	i. Pricing; ii. Competitor study	i. Identify possible mechanisms and production processes; ii. Pricing	i. Identify possible mechanisms and production processes; ii. Pricing

2	Define	i. Design a brief (all inclusive); ii. Project schedule; iii. Project management	i. Design a brief (marketing); ii. Project schedule (including product launch); iii. Project management	i. Design a brief (material and production); ii. Project schedule (manufacturing; iii. Project management (manufacturing plan)	i. Project schedule (manufacturing and delivery); ii. Project management (manufacturing plan)
3	Develop	i. Explore design solutions; ii. Mock-up test; iii. User or stakeholder evaluation	i. Explore possible business strategies/models; ii. Evaluation (positioning and pricing)	i. Explore engineering solutions; ii. Mock-up test; iii. Evaluation (engineering feasibility)	i. Explore production solutions; ii. Mock-up test; iii. Evaluation (manufacturability)
4	Deliver	i. Final visualisation; ii. Final prototype; iii. Production drawing	i. Promotional statement; ii. Final business and marketing plan; iii. Maintenance plan	i. Production drawing; ii. Production plan; iii. Final production	i. Production plan; ii. Final production; iii. Packaging, transportation and installation
5	Evaluation	i. Quality inspection; ii. User observation; iii. Self-reflection on the design process and decision-making	i. User feedback	i. Quality inspection; ii. Revision or refinement	i. Revision or refinement

Please note that the above sample cases are particularly relevant to non-technological design projects and that few involve significant input to support a new mechanical or technological design, in which the hypothesis may lead to an important technological breakthrough.

It is obvious that many tasks undertaken by individual actors overlap with the stages handled by designers. In addition, designers assume a front-line role in interacting with users and discovering and meeting their needs. They are also required to act as an integrator or a hub to connect dispersed information and formulate end results that can meet the needs of end users. This is far beyond a single profession and it is even more challenging in the context of user-centred design. To better understand the real needs of users, designers adapt different user research methods from other disciplines, such as anthropology, social sciences or ergonomics. More importantly, designers and researchers cannot understand users without addressing more complex social issues and society's call to empower stakeholders to take part in the decision-making process on design for their community. In Hong Kong, users/stakeholders were first invited to take the role of designers in the design process in early 2000, in line with the educational and governmental agenda, and business organisations are slowly catching up.

Participatory design, with a co-design or co-creation platform linking designers with multidisciplinary experts and other stakeholders, emerged in Hong Kong nearly two decades ago. For instance, community stakeholders have been involved as experts in their own lives in decision-making on research and design related to their **living environment** since 2001 (Kwok, 2004). Participatory design has thus become an effective approach to collecting user feedback and relevant information in Hong Kong. Similarly, Demirbilek and Demirkan (2004) adopted a **participatory design approach** to examine users' concerns about the safety, usability and aesthetics of **residential design** and to improve the quality of life of independent older people. Sanders and Stappers (2008) further **defined co-creation or co-design** as **collective creativity through collaboration** between designers and people without design training, working together in the process of design development. They described the development of co-design from the participatory design approach movement that emerged in the 1970s. In addition, Nigel Cross advocated **'user participation in design'** to improve the design process since 80's. This approach involves the participation of a designer and a design researcher to reflect on and criticise user-centred design to move towards co-creation with a more people-centric and networked approach, giving more weight to the views and skills of active users instead of focusing on products or manufacturers.

However, this approach has limitations when engaging with the typical **'wicked problem'** (Buchanan, 1992; Dalsgaard, 2014), in which the scope of design is entangled with multiple kinds of domain knowledge and other factors. In particular, it is challenging for both designers and non-designers to integrate ideas without knowing the relationship between unknown factors, such as how people react to different types of products and situations. The design team cannot exhaustively collect and analyse big data to identify useful information during the generally short duration of a workshop. Therefore, this research was based on the premise that if the project team can **develop a prototype early in the development phase**, more promising results can be achieved more quickly.

1.1.1.4 Black box: Inside the brain of designers

Before delving deeper into the mechanism of prototyping, this section seeks to understand one of the major phenomena in the design process involving designer cognitive issues.

The design process has been studied for its creative potential, which drives innovation and integrates thoughts in a multidisciplinary environment. Unfortunately, aesthetic creation or the form-giving process (including prototyping) remains poorly defined in terms of the functioning of the brain due to differences in personal perceptions of visual elements and the gap between verbal and visual language and practical and tacit experiences.

Designers' '**black box**' process or way of thinking should not be considered as a complete design process. Instead, it can be seen as a rather unique process and type of design thinking. I argue that the term refers to the integration of ideas and exclusion of other processes, such as user research and testing, manufacturability analysis, material and structural exploration and production planning. As Jones (1992) suggested, during **black box** thinking, **integration**' involves **i) experimentation** and **ii) a creative leap**. Different types of experiment are involved, such as **proof of idea** by **sketching** or **paper model** testing. As this research focused on the implicit process of designers who integrate ideas into a product, explicit experiments, such as material properties testing and mechanical study, were excluded. The term 'implicit experimentation' was adopted to identify a specific designer experience during the idea integration phase, in particular the proof of idea through prototyping (sketching).

1.1.1.5 Effects of imageability and concreteness on design ability

Kroes (2002) argued that the lack of clarity and understanding of the nature of the design of technical artefacts is problematic.

People differ in intelligence and perform differently in the design process

The design process is a practical framework helping designers to more effectively manage a project themselves and with collaborators and clients. Abstract and generic descriptive models such as the well-known double diamond model proposed by the British Design Council, with its four main stages, or the five-stage design thinking model of the Stanford d.school, provide an overview of the complete design process. Other similar models include more detailed or specific components and the iterative nature of the design process. On the one hand, they help us to clearly identify individual thinking or working processes in a messy design project in terms of the iterative or abductive nature of combining different factors, such as ideas, actors, environmental and social contexts. On the other hand, they oversimplify the processes, work and inputs of the designers.

This is problematic, although more sophisticated design process models have been developed. The study of product evaluation, such as product design assessment tools, is well developed. Theories such as product semantics and emotional design also help evaluate design concepts and inform designers of the most reasonable design strategy. However, from my personal work experience with other designers, studies of creative practices (e.g. form-giving or prototyping) and design evaluation (e.g. product assessment methods) still operate in two distinct worlds. Design evaluation has received more attention from academics. However, **form-giving or prototyping** remains poorly defined. Why can we draw even as children? Why can some people draw better than others? Why can some people create objects without drawing? Scientists in education and psychology have highlighted several factors conducive to drawing skills, such as i) a stronger visual memory; ii) better fine motor skills to control the pencil; iii) know-how, skills and a mental library regarding the manipulation of tools and materials; and iv) spatial intelligence to support mental rotation. All of these capabilities help people to draw and create three-dimensional objects. The question is whether well-trained designers can sketch and create models better than non-designers. Obviously, people can master different skills that are not related to their career or education. Therefore, when organising a collaborative workshop, grouping the participants according to their disciplines is not appropriate. The exact intelligence profile of individuals should be used to form teams if teams require multiple and diverse talents. The most common practices are the measurement of IQ and self-evaluation.

Poor understanding of how designers master visual elements

Many studies have focused on the development of evaluation and visualisation tools for production. It makes sense to accrue rich product design knowledge related to production or manufacturing engineering. Unfortunately, although there are sophisticated design process models, the latest visualisation tools for design cannot replicate the approach to doing (reasoning) of designers, except for the realisation of a product form, which occurs during later stages of a project, such as rendering, assessment and production. There is a need to develop visualisation models or tools to facilitate idea generation (not generated by a computer) and exploration. This is closely related to the reasoning process during sketching (or using computerised visualisation tools) and the conceptualisation process in the minds of the designers.

The transformation of verbal into visual concepts – Imageability and concreteness

Product design or prototyping is a visual-spatial inference-driven process. With a systematic and holistic understanding of design reasoning, designers and design managers can tackle the mysterious (tacit) and complex challenge of achieving more objective, explicit and effective communication and measurement. This promotes better and more refined thinking and the more effective management of creative projects and alignment of work patterns as reflective design practitioners. This thesis sought to identify what elements and factors constitute the visual-spatial reasoning adopted by product designers. One of the main concepts is **imageability**. The term was first coined by Paivio et al. (1986) to describes the **concreteness** of words that give rise to a sensory experience. More concrete objects more easily create a sensory experience. Thus, words with greater concreteness should also have greater imageability and vice versa. There are exceptional cases in which high concreteness is linked with low imageability. Concreteness was one of the main measures used in this study. As a commonly known and well-accepted approach to idea brainstorming and the early insight or concept development phases, the formation of verbal or written concepts plays a dominant role in design workshops. For instance, making notes or collecting ideas on Post-it notes is a way to facilitate communication in a group. Generally, workshop participants need to imagine and draw (or make) a sketch (or prototype) based on the denotation (or even the connotation) of a word or sentence. Therefore, understanding the transformation of verbal concepts into visual concepts that provide sensory experience is critical to the success of prototyping and the ongoing development of product design.

1.1.2 Technological development in design

Compared with manufacturing engineering, which aims to produce a predetermined object, the discipline of product design seeks to put forward and/or make new objects by shaping materials and people's behaviour. Product designers use materials to create meaning and provide a function to communicate and meet the needs of users. For instance, a furniture designer formulates a seating solution by imagining an appropriate structure that provides physical support and a new meaning or value for a specific type of user, using the best materials and production methods. Thus, manufacturing techniques are always concerned with design reasoning.

The issue of technological development is a critical factor or major constraint that affects and guides the decision-making of product designers. Product design is a discipline dedicated to the materialisation of culture through form-giving. That is, a discipline that manipulates physical materials to create a physical structure or prototype of an idea or concept to give birth to a functional means for people.

I believe that most senior product designers can imagine the manufacturing process in their minds. For instance, designers are able to imagine a hammer progressively forging a flat metal plate into a bowl structure. This argument was integrated into the research questions asked in this thesis. In addition, I proposed that this thinking approach is a crucial form of reasoning in design and a type of visual-spatial reasoning because of the process of animating changes in the structure or form of the material. By examining how designers manipulate materials processing or manufacturing methods in design, we can learn more about their reasoning, contributing to the theory of design thinking.

There are three main concerns about the manufacturing technologies involved in the daily design process.

(I) Traditional crafting techniques

Before the era of mass production with synthetic materials, craftsmen worked only with natural materials, such as wood, stone or other organic (animal bones) or inorganic materials (minerals). In principle, the subtractive manufacturing method (cutting materials for definitive purposes) was used in machining or hand tools, for instance milling, drilling and turning.

Crafting techniques aimed at changing the physical properties or structure of materials, such as bending, rowing, twisting, stretching and compressing, are essential for craftsmen and designers to envision and explore their design concepts.

The idea of manipulating materials helps designers think about their ideas.

(II) Contemporary manufacturing technologies

Manufacturing technologies have been developed to support one-off, batch and mass production. The processes include forming (including the aforementioned crafting techniques), machining, fastening and assembly, casting, moulding, additive manufacturing or surface finishing. The new advanced manufacturing technology is the additive manufacturing process, usually called rapid prototyping or 3D printing.

In most manufacturing processes, articulating ideas helps designers, especially senior designers, to anticipate and manipulate possible outcomes and constraints in terms of design criteria and design intent.

(III) Materials technologies

Choosing appropriate materials and considering the properties of the materials are essential for designers to create an object using certain materials to achieve a certain structural and aesthetic function. Natural and artificial materials involve different types of manufacturing process, as mentioned earlier. Depending on the requirements of the design, designers may be confronted with complex reasoning to choose the right materials. For instance, opaque, transparent or translucent materials may affect the visual and functional properties of a design. Designers must consider differences (e.g. pros and cons) through their visualisation techniques (internal or external means).

Although technological understanding can be articulated and transferred to workshop participants, it is not reasonable to introduce this knowledge in a short time. It is also not practical, as there are many different and new technologies that the workshop planner may want to incorporate as a means of production, such as 3D printing. In most workshops driven by social aspects or problems, technology is not introduced until a specific problem space and solution have been identified. Otherwise, it would be meaningless. In contrast, when research only focuses on the early prototype process, technological understanding becomes less important. However, it is a potential research area that can help better understand how to improve the performance of designers in the middle or later part of a project. This issue can inform future research.

1.1.3 Service, environmental and social issues in the design process

In addition to manufacturing concerns, designers are concerned about recycling, maintenance and other service issues during the design process, especially when identifying and defining a design problem or insight. For a prototype to become a central entity related to various concerns and interactions, it is necessary to adopt a holistic design approach. This explains why the visualisation of the prototype is essential for the design process when a design team undertakes a complex scenario involving many stakeholders and factors.

For instance, in recent years, more and more customers and designers have focused on creating a sustainable economy. They imagine a well-thought-out system of sustainable consumption involving reused or recycled materials and biodegradable materials. The performance and sustainability characteristics of materials, new sustainable production and logistics approaches and the recycling system have created new constraints and new opportunities for design reasoning in the development of sustainable products. This scenario is more complex than the conventional user problem.

More and more innovative business models are involving the empowerment of underprivileged communities and the development of indigenous culture. Design reasoning in this area is a promising thinking model that can integrate different contexts in terms of developing new social innovation strategies. Design for environmental conservation and societal contributions (not only for profits) is an emerging design criterion as important as boosting business growth was before.

In light of the above discussion, the scope of this research followed the theme of design for communities rather than a traditional product used by a single type of end user.

1.1.4 People's perspective in design thinking

The preceding sections discuss design thinking and various technological contexts (production, maintenance or related services). Therefore, this section addresses people, including users, the consumer market and designers.

1.1.4.1 Consumers or users

It is always useful for designers to know the needs of users or consumers. There has been more discussion of this topic than of the process of designing itself. For instance, theories of the users' perceptions of aesthetics or emotional experiences in product design have been discussed extensively. Knowing how users or consumers perceive visual elements is useful and practical for effective design outcomes. It is obvious that designers adopt certain rules, such as colour theory, product semantics or affordance theory, to solve a design problem.

1.1.4.2 Refining design guidelines to facilitate collaborative prototyping

How do designers create forms? More specifically, how can product designers make sense of a concept, either its symbolic function or its structural function, or both, by manipulating visual elements and materials?

There are two main common practices in the career development of designers or visual thinkers among designers identified as unique talent by most people. First, designers are good at observing emerging trends in society or experiencing through participation, such as changes in ideology, lifestyle and technological application. Second, inspired by their observations and experiences of changing society (the outside world of designers), designers look for structural patterns in a fragmented environment or a chaotic situation in the outside world (called being inspired and making sense of this inspiration). This can i) inspire new interpretation strategies, such as new functions, new definitions of things, new ways of thinking or new ways of seeing things; and ii) inform new types of visual expressions or experiences, such as new visual structures, new materials and surface finishing or any new visual form of expression in which a new visual culture can be proposed. In a pragmatic way, designers try to enrich living conditions by meeting the criteria and challenges of the outside world and compose new forms of visual language that can be understood by other stakeholders. From this perspective, it is essential for a junior designer to learn how to acquire useful visual information from the study of the world and to formulate effective and innovative visual design strategies.

Is it possible to identify a more subtle difference in the functioning of prototyping and visual-spatial reasoning, and will this difference appear in the latest collaborative design environment? If there is variation, what is it? How does it work and can it be improved?

Two main variables informed the breakthrough of this study. Their effects on the way of reasoning of designers in collaborative mode were further examined. The aforementioned **imageability** and **prototype (sketching)** were the main variables used to refine the guidelines for design workshop facilitation, such as how concreteness and abstractness enable **team communication and collaborative prototyping**. In addition, in terms of user evaluation, a prominent benefit of improving collaborative prototyping is the shift from meeting functional needs to focusing on the user experience, as the design team can focus on the user sensory experience and collect user feedback if the prototype is ready in advance. In simple terms, fulfilling functional needs (e.g. comfort-ability) is no longer sufficient in participatory design practice. Instead, we should promote **satisfaction with usability, awareness of self-identity, sense of community,**

ownership, pleasurable experience and/or social responsibility through an easier prototype evaluation in every community design project. In other words, a prototype is essential to a successful design.

1.2 Objectives of the thesis and research questions

1.2.1 Introduction: The need to foster prototyping research (part of the design process)

How do designers manipulate visual elements and materials during prototyping? We can consider this question in light of the definition of design offered by Galle: a type of action in terms of plans, intentions and practical reasoning. Designers bridge the gap between the function and structure of an artefact (Galle, 2002). This is a process of materialisation that not only involves ‘yes or no’ and ‘true or false’ questions, but also ‘better or not’, ‘possible or not’ and ‘fit or not’ questions, requiring reasoning about communication between artefacts and participants (designers and other stakeholders).

1.2.2 The missing piece of design knowledge in practical creation

As Burdick (2009) proposed, current studies of design thinking in design research are limited by a misunderstanding of design. She asked how it is possible for educational research to explicitly construct design concepts without ever mentioning the value or professional practice of actual designers. In addition, business studies have adopted a design thinking approach, shifting business practices and ways of thinking from an analytical approach to a more generative, creative and risk-taking approach. However, although design thinking has been praised for solving various problems (from education to business) and enabling multidisciplinary collaborations, Burdick argued that this emerging tendency to adopt design thinking may disregard artefacts and their making, that is, the dominant activity of designers to engage the world. As Burdick (2009) commented the hands-on creation of material culture can bring the learner in-depth knowledge and understanding than passively receiving the knowledge.

Moreover, product design is not only the result of functional objects providing mechanical functions or physical support for users; it also offers meaningful concepts with symbolic and cultural value for users and stakeholders.

In most design schools, product designers acquire their professional skills in form-giving through conventional hands-on training. For instance, sketching exercises and model making (physical and virtual modelling) are two main skills taught to every junior student. First, training in sketching helps designers to develop their articulation of representation techniques and mental models of two- and three-dimensional visual structures. Second, model making (physical) enables product design students to imagine a possible solution taking into account the visual and tactile experiences of the materials, the mechanical properties of the structure and the user experience. Virtual modelling techniques help accurately represent a concept and offer more reliable validation or evaluation. These two hands-on training techniques help make sense of the form and function of a product by considering the aesthetic experience and meaning creation for communication in a particular social system (e.g. a product for specific social classes and representing the corresponding social value). Sketching and model making are forms of prototypes.

With the introduction of human-centred design and consideration of user needs, preferences and consumption patterns, design research from the user's perspective has received more attention than research from the designer's perspective. There has been little research on the positive contributions of the aesthetic value or styling value of a design. Of course, research on the effectiveness of product interaction and the emotional quality of a product has been discussed extensively. Tonkinwise (2011) mentioned that design-as-styling or form-giving has been ignored in design thinking research. This is also the case in the study of design thinking and participatory design: the style and meaning of form language have been rarely discussed or implemented. This 'job' relied on the input of professional designers in most of the design workshops I organised in Hong Kong.

Although they do not necessarily focus on the aesthetic value of a product in each project, designers pay attention to the manipulation of visual materials and its relationship with functionality, usability and the user experience. Do participants without design training need to consider aesthetic or visual values in the participatory design process? If not, does the dominance of professional designers have a negative effect on public participation and ownership? If yes, why is it less addressed when it is essential? How can we improve this situation?

In addition, this research sought to prove that prototyping is an intellectual reasoning ability of visual-spatial elements or structures for the 'sense-making' or imageability of a product concept, rather than a matter of aesthetic outcome or styling work. The results also showed that the 'sense-making' or imageability of prototyping is a state of contextually preferable relational configuration of images and texts, based on the relationship between the designer, the user and the stakeholder interpreting or interacting with it.

1.2.3 Extending foundational design theory to enhance the facilitation of design workshops

Design is a relatively young discipline that urgently requires more discussion and rigid study of foundational theories. Understanding the workshop method (Westerlund, 2007) in the context of education will help to develop participatory design.

In this thesis, I sought to understand early phase prototyping adopted in the product design process from three perspectives: the designer (**my personal experience**), design workshop facilitators (**experience of other designers**) and analysis of the performance of real workshop participants in early phase prototyping (**empirical understanding of participants with different backgrounds**).

I adopted the revised version of Bloom's taxonomy proposed by Anderson et al. (2001), a well-established model, to cluster workshop training actions and identify the relationship between learning outcomes and the four stages of the general design process based on the double diamond model proposed by the British Design Council (Table 1.3). This matrix supported the development of research questions in the second half of this research work.

Table 1.3 Matrix of workshop training actions based on Bloom's six levels of learning taxonomy and the four key stages of the design process.

Levels of learning		Actions commonly taken in workshop training	Define	Discover	Develop	Deliver	Learning outcomes
I	Remember	To describe, define, identify, …	*	*	*		Be able to remember factual answers, recognise the context, etc.
II	Understand	To classify, demonstrate, interpret, …	*	*	*	*	Include the ability to translate, interpret and extrapolate
III	Apply	To apply, produce, sketch, solve, …			*	*	Know when to apply, who to apply it to, etc.
IV	Analyse	To analyse, categorise, differentiate, select, …	*	*	*		Break down knowledge into parts and show the relationship between the different parts
V	Evaluate	To appraise, criticise, compare, …	*	*	*		Explain the criteria of the project and make decisions with reason
VI	Create	To compose, construct, design, hypothesise, plan, …			*	*	Understand synthesis skills

As Nigel Cross (2006) mentioned, the nature of design ability is poorly understood; it is often considered a mysterious talent. The main difference between design and natural science lies in the former's initiating of new forms and its essential mode of abductive reasoning. It refers to the logic of conjecture, which some researchers have called 'productive' or 'appositional' reasoning. From my personal experience as a design practitioner, the goal of a product design activity is to materialise a concept that meets the needs of individuals (functionality, usability and cognitive experience (e.g. pleasure) of consumers and users), society (e.g. custom, social value and economic value) and the environment (e.g. sustainability). This study of prototyping emphasised this goal.

1.2.4 How to facilitate designers' reasoning to solve complex problems?

In reality, we encounter complex scenarios that involve both the traditional paradigm of making sense of production (e.g. effectiveness), user interface (e.g. ergonomics) and business innovation (e.g. capitalism with mass production and lower costs) and emerging values relating to the implementation of sustainability (e.g. social responsibility), social interactions (e.g. beneficial to communities) and social innovation (e.g. local production, local consumption). Unfortunately, these objectives are often presented as contradictory in nature, such as business growth vs. sustainability, involving a more difficult reasoning process for designers or design teams. This requires more advanced skills and knowledge in terms of thinking tools and techniques compared with previous design training at school. The tasks of today's designers are more diverse yet more confused than they were just two decades ago. For instance, the design of a personal computer is no longer simply the effective integration of a screen and a keyboard. A PC must not only be a production tool, but also a platform for communication, study and entertainment, able to connect to others and the world. The design of PCs is also affected by high levels of mobility, such as those afforded by mobile phones or tablets. Designers must make decisions on social connections, mobility and mode of participation, which may create a new future for PC technology.

How can we ensure that current reasoning methods for design, especially prototyping, are sufficiently useful and effective to tackle these new complex scenarios? In this thesis, the main study identified and explored prototyping reasoning methods adopted in the design process by product designers. This is a vast but fundamental topic. Therefore, to limit the research scope to in-depth analysis, the early phase product concept prototype, usually generated in the first round of ideation in a typical design thinking workshop, was the focus of the thesis.

1.2.5 Ontological understanding and research contributions

The essence of prototyping is not problem solving. Instead, it is a human activity with a tendency towards differentiation, innovation and meaningful creation. Designers, with their unique physical and mental ability to integrate materials, tools and technologies, play a key role in meeting the emerging needs of users and those of social and ecological systems. Similar to all human beings, designers perform extremely intricate, exquisite and distinctive actions during prototyping compared with their counterparts to meet the specific needs of users. It is important to understand the users' problems, but also how the designers react to and approach these problems. These characteristics generally attract the attention of non-designer or non-artistic people and researchers fascinated by these creative activities because of designers' unique way of reasoning in terms of appropriateness, the transformation and interpretation of physical and symbolic materials and the meaningful interactions between users, artefacts and the environment. This thesis also argued that the individual abilities of designers may affect the pattern or way of adopting reasoning approaches to infer or make sense of a design concept. To this end, it described the experiences of individual designers in the process of reasoning about the appropriateness of a design concept through design thinking and its correlation with design constraints, including technologies, users, business, the environment and society. Limited by resources and specific knowledge, I only implemented a self-evaluation method to collect the reasoning distribution profile of the sample (workshop participants). The five main reasoning or thinking preferences used in individual thinking patterns to deal with daily issues (studying or working) were collected: 'visual', 'verbal', 'mathematical', 'musical' and 'kinaesthetic'.

To construct an ontological description of prototyping, **constructionism** was the central philosophical perspective guiding the methodology and research design of the thesis.

1.2.5.1 Contributions

The contributions of this research are as follows.

First, this thesis expands the ontological understanding of the correlation between concept generation and prototyping in the product design process and the theoretical development of design thinking. The research contributes to the formal and authentic understanding of product design practice, facilitating the decision-making of design workshop facilitators and designers and providing an effective design tool supporting product design development and design education in a participatory design environment. Second, the thesis emphasises the importance of prototyping as a major tool adopted by designers to solve complex problems as a form of knowledge distinct from other reasoning approaches, such as linguistics and mathematics. Third, it was assumed that each designer adopts his/her own pattern of reasoning, affecting decision-making. Therefore, observing the nuanced approaches of designers was useful for explaining the complexity of prototyping or the design process. Based on the results, a holistic solution focused on a design framework to facilitate the formation of a prototyping strategy in the product design process was proposed. The findings also contribute to the debate on design as a form of intelligence (Cross, 2006, p. 22). How can a 'tangible' solution be envisioned? It is difficult without professional training. Therefore, this thesis sheds light on part of the puzzle.

In addition to the above pragmatic theoretical contributions, a thorough understanding of prototyping in product design can further inform i) the refinement of the current product design curriculum; ii) the advancement of computational tools for product concept visualisation and generation; and iii) the optimisation of research on product design and development processes to improve collaborative prototyping in participatory design workshops.

1.2.5.2 Summary of research arguments and approaches in the thesis

Table 1.4 Rationale of arguments and approaches in the thesis.

Domains	(A) Design reasoning	(B) Product/Interaction design	
Challenges in building design knowledge	Unclear explanation of design concept prototyping	External challenge of prototyping undertaken by designers and non-designers	Internal challenge of prototyping undertaken by designers and non-designers
Problem areas of the study	The transformation of verbal means into visual forms and structures is not explicitly described with respect to physical and symbolic interactions with users. Design reasoning is	1-Diverse user and community needs; 2-Wicked problems due to complex situations and factors	1-Insufficient reasoning methods or techniques to deal with emerging complex global problems (e.g. from the product perspective to the service system perspective); 2-The individual preferences and abilities of designers are factors affecting or limiting design exploration

	understood at the abstract level and still perceived as an arbitrary or artistic action, i.e. a black box		and decision. The various styles of cognitive thinking, such as visual thinkers or verbal thinkers, may lead to someone dominating the process
Main research questions	Argue that the **early phase prototyping** process (especially verbal to visual reasoning) requires a specific and explicit framework	Argue that the **framework of the participatory design approach** (Sanders et al., 2010) should include early phase prototyping components, which are essential to facilitate collaboration between designers and non-designers	Examine the **personal experience of early phase prototyping** of individual designers and its correlation to make sense of a design through verbal and visual clues
Expected research outcomes	To construct the **ontological understanding of early phase prototyping** in the product design process (to understand the black box of the **transformation of abstract concepts to tangible experiences**)	To prove that **early phase prototyping** in product design practice is an **inference technique** driven by contradictory concepts: **a dialogue** between **abstractness and concreteness** generated by designers as major thinking techniques **integrated in design (wicked) problems**; It also affects communication between designers and non-designers	To broaden the **framework of the early phase prototyping approach,** which currently **has no structured methodology,** which weakens the ability to generate appropriate conceptualisation and prevents the development of final prototypes
Methodologies	**Phase I- Case studies** based on a self-reflection approach were used to construct a model of visual-spatial reasoning in product design based on the reflective experience of the researcher on the product design process. This led to the development of a set of questions and a basic research structure illustrating the different types of prototyping adopted in the design process. Phase I was a stepping stone for Phases II and III. **Phase II- Case studies** based on interviews with open-ended questions to analyse the experience of other design workshop facilitators and their reflection after guiding the participants. **Phase III- A design task** and correlational study on a one-hour design exercise from idea brainstorming to early phase concept prototyping (scenario design sketching) was carried out and analysed through content analysis. The theme of the exercise was ‘to design a multigenerational bench in a park’. The results of the three phases were compared and integrated to formulate a descriptive framework for prototype-ability.		

1.3 Structure of the thesis

The main objective of my research was to identify and describe the factors that influence the **performance of the prototyping process** (concept sketching in a specific scenario) during the early ideation phase in the context of design projects adopting a participatory design approach. The diagram below illustrates the approaches and research logic for the theoretical construction of the thesis.

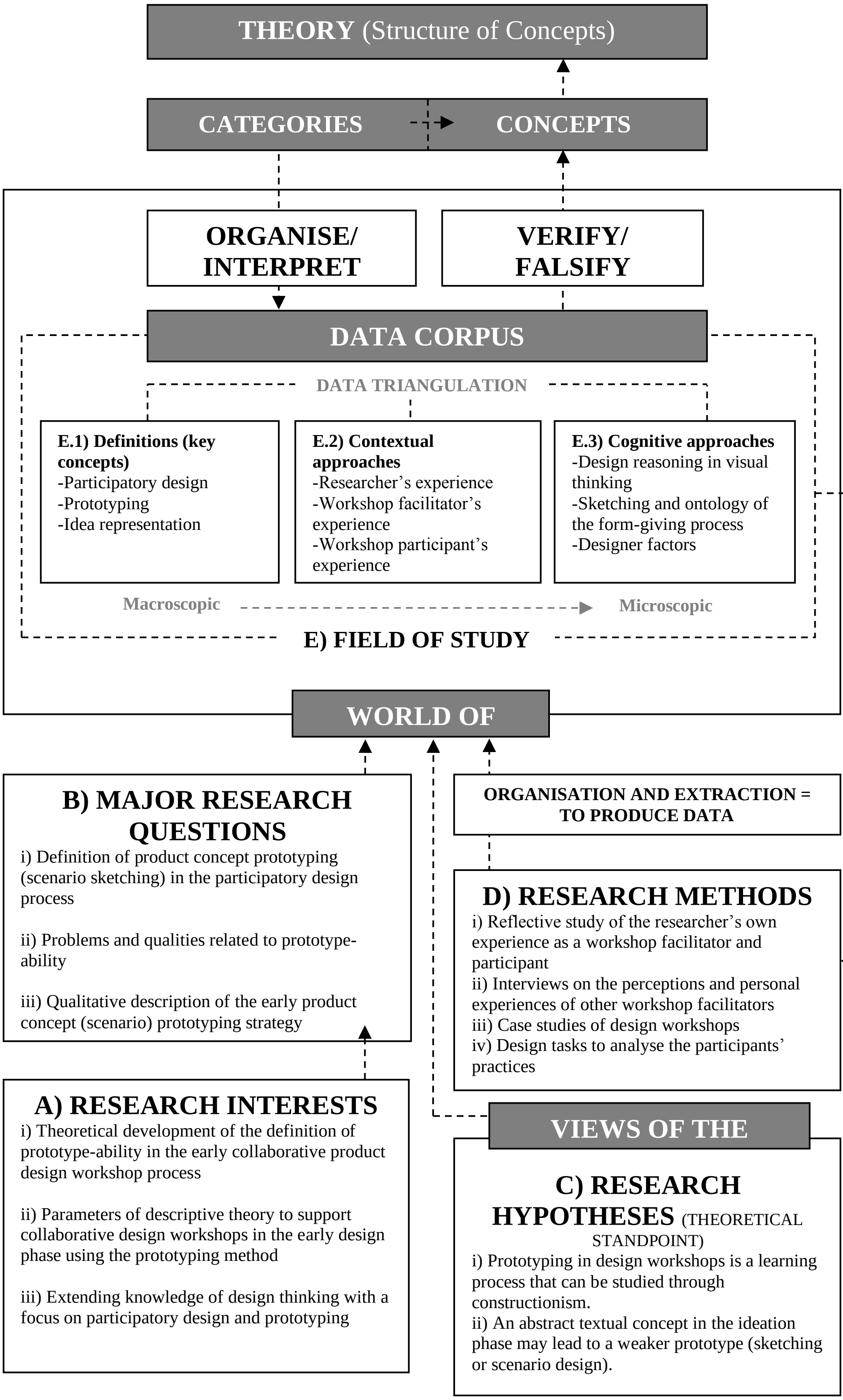


Figure 1.5 Diagram of approaches and research logic for the theoretical construction of the thesis.

Chapter 2 Literature Review

2.1 Characteristics of prototyping as reasoning in product design

2.1.1 The foundation of design research

2.1.1.1 Interaction design and situational product design

According to the fundamental definition of industrial design proposed by John Heskett (1980), 'industrial design is a process of creation, invention and definition separated from the means of production, involving an eventual synthesis of contributory and often conflicting factors into a concept of three-dimensional form, and its material reality, capable of multiple reproduction by mechanical means'.

Similarly, Buchanan (2001) proposed that 'design is the human power of conceiving, planning, and making products that serve human beings in the accomplishment of their individual and collective purposes'.

As Buchanan (2001) argued regarding the evolution of the meaning of '**product**' in design, the focus of design in research and practice shifted from grammar and logic in the early part of the 20th century to rhetoric and dialectic today. According to Buchanan, there are four orders of design.

Buchanan stated that we have entered a new phase in the value of design, moving from visual symbols and things (graphic and industrial design, the first and second orders of design) to actions and environments, suggesting that our communication and constructions are forms of action. Designers should be more aware of how people select and use products in their daily lives, ensuring that their design can support their actions and experiences. This gives rise to the third order of design: a new domain of design thinking and professional practice called **'Interaction Design'**. This new domain draws attention to the relationships between people through the mediating influence of products, referring not only to physical objects, but also to a type of experience, activity or service.

The fourth order of design suggested by Buchanan focuses on environments and systems, called **'Environmental Design**', from systems of 'things' to human systems integrating **information, physical artefacts** and **interactions in the environmental situation** between living, working, playing and learning.

Based on my experience of the prototyping process, current workshop training is designed as a discipline to deal with complex situations with holistic and empathic perspectives, with a focus on interaction design (**interactiveness**) and environmental design (**situatedness**).

2.1.1.2 Culture and time shape the nature of design

Analysing environmental and interior design practices, Thompson and Blossom (2015) argued that the conceptions and ideas affecting the way designers shape design are related to the **culture and time** in which individuals have been educated and trained, and to the institutional and corporate structures and practices that surround them. Wang (2015) cited Galle's (2002) suggestion that there is a direct connection between an individual understanding of design and the practice of designers. The way designers conceive the nature and purpose of design affects their practice (Galle, 2011). Cultural and temporal concepts are specific to the situation and the site. These factors affect most community or social design projects.

2.1.1.3 Buchanan's perspective on products in the context of a complex world as the basic framework for the goal of prototyping

Buchanan (2011) argued that new design research should no longer examine form as a shape or visual pattern from an external perspective, but should instead focus on form as a synthesis of what is **useful, usable and desirable**. It should address the content and structure of performance, human affordances and product voice. This claim is similar to Jordan's (2002) theory of the hierarchy of consumer needs: functionality, usability and pleasurable experience. Finally, Buchanan discussed product design from a phenomenological perspective. ‘In essence, form becomes a temporal phenomenon of communication and persuasion, as human beings engage with products’ (2011).

Buchanan claimed that for a product to ‘work’ today, we need a **more complex design** to create desirability. The different perspectives on products proposed by Buchanan are relevant to the foundational framework of this design research.

2.1.1.4 Goldschmidt’s perspective on visualisation in design

Visualisation technologies in the product design industry have developed rapidly over the last three decades, from traditional forms (hand sketching/drawing tools) to advanced systems (digital drawing tools and 3D software with intelligent programming). Visual information plays a key role in the design process (Goldschmidt et al., 2006). According to Goldschmidt (2017), sketching is essential for prototyping, particularly for planning. Therefore, it remains a valid method of exploring ideas.

However, we cannot be sure that workshop participants are well trained. As participatory design workshops adopt a bottom-up design approach and involve stakeholders in the design process, sketches were used as the main output in the design task of this research. Sketching can be done professionally or in a very primitive way for communication purposes. In reality, representing a mental concept (in one’s mind) or transforming a verbal concept into a physical object (such as a sketch) is challenging for many people. However, there has been no in-depth investigation of this topic.

2.1.2 Design thinking and design reasoning in prototyping

To understand the definition of visual reasoning, it is important to recognise the logic of perception in the visual world and the philosophical definition of its related concepts.

The three ways of design thinking

Kimbell (2011) collected different ways to describe design thinking, leading to three perspectives on design thinking: i) design thinking as a cognitive style; ii) design thinking as a general theory of design; and iii) design thinking as an organisational resource. To compare these three perspectives, the characteristics of an individual concept are analysed in terms of five areas: field of focus (e.g. people or discipline), purpose of the application (e.g. solving problem or innovating), definition of design thinking (e.g. concept as intelligence or a reasoning method), nature of design problems (e.g. design problem or organisational problem) and application sites of design expertise and activity (e.g. traditional design discipline or other disciplines).

2.1.2.1 Reasoning – A philosophical perspective

Judging probability

Manktelow (2012) recommended understanding and explaining people's thinking and reasoning based on how they judge probability, which is not just a technical (statistical) matter. He pointed out that we generally compare normative systems, and that this comparison means different things to different people. Ideas related to probability can be defined in four ways: a type of objective unbiased probability (logical possibility), frequency, propensity and a type of subjective probability (degree of belief). Manktelow's approach to using probability to explain reasoning is effective in that the essence of reasoning is to look for possible answers.

Theoretical reason and productive reason

According to the definition of theoretical reason in the *Cambridge Dictionary of Philosophy* (Audi, 1999), in *Metaphysics*, Aristotle identified mathematics, physics and theology as the subject matter of theoretical reason. Theoretical reason is traditionally distinguished from practical reason, as the former is a faculty for identifying guidelines for good conduct and deliberating on proper courses of action. Conversely, practical reason involves 'making': shipbuilding, sculpting, healing and so on.

Kant distinguished theoretical reason not only from practical reason, but also (sometimes) from the faculty of understanding at the origin of these categories. As defined in the *Cambridge Dictionary of Philosophy* (Audi, 1999), with its own a priori concepts (‘ideas of reason’), theoretical reason regulates the activities of understanding, which, I argue, modifies the decision of the designers. According to Kant, theoretical reason seeks an explanatory ‘completeness’ and an ‘unconditionedness’ that transcend what is possible in experience.

In conclusion, as a faculty or capacity, reason can be considered as a hybrid composed of theoretical and practical reasons or as a unit with both theoretical and practical functions. Reason is sometimes contrasted with experience, sometimes with emotion and desire and sometimes with faith. Undoubtedly, design reasoning falls into the realms of theoretical reason and practical/productive reason based on Aristotle’s and Kant’s definitions. Overall, a prototype is an end product of reasoning.

2.1.2.2 Design reasoning – A unique ability for innovation

As described by Ferguson (1994), technological design has become a complex and hierarchical social activity. This hierarchy reflects the division of labour between designers and manufacturers since the 18th and 19th centuries. Ferguson pointed out the disadvantages of ignoring hands-on experience and non-verbal reasoning in engineering design from a historical perspective, using significant cases.

Do we know the exact design process, in particular the conceptualisation process, in the minds of product designers? There is a gap in discussion of the way of thinking of designers and the design thinking process. Visual reasoning is the most important ability of designers, distinct from professionals in other non-design disciplines, such as literature and music. It shares some similarities with activities in mathematics and physics, such as conducting geometric and physical analyses. However, the visual reasoning of designers is strongly correlated to the production process, to ‘making’ things. This is unique. Product designers are heavily involved in manufacturing, which uses a variety of production methods. Unlike graphic designers, product designers are usually confronted with complex reasoning with diverse constraints, which should contribute to the knowledge of design thinking.

As previously mentioned, the story begins in the 13th century, when Giotto drew his perfect circle in red paint for the Pope. Most people associate the talent of drawing with the job of designer. However, this conclusion is superficial and insufficient. I am sure that Giotto had more skills than fine motor coordination. To excel in architectural design, for instance, the ability to visually imagine and represent 2D and 3D visual structures and elements is crucial. Mathematicians excel in abstract numerical and spatial correlations, which they use to think mathematically. Literary people are sensitive to verbal language and perform better in verbal thinking. Painters are sensitive to visual language and excel in visual thinking. What about designers?

A Japanese joinery woodwork expert had an intriguing discussion with a student who trained as a designer during a wood workshop he conducted in Australia in 2015. The expert discovered that his student had a very good sketching technique that he lacked, and explained that he would be a good designer if he could draw with precision. I also interviewed two craftsmen with traditional apprenticeship training (woodwork and metalwork). They also performed very well in their fields, but visualisation was not their strength. Therefore, it seems that good craftsmen are not necessarily good at drawing or sketching. This phenomenon raises an interesting question: if a designer is expected to create a beautiful and functional form, does s/he need to be better at drawing or craftsmanship? Or both? Or are other abilities needed?

Designers have ways of reasoning beyond sketching and other forms of visualisation. Designers perform verbal and visual reasoning on paper (externalised) and simultaneously in their minds (internalised). Thus, a sketch cannot record all of the thoughts of a designer when conceptualising a concept. This phenomenon has been described as a 'black box' in the process of design thinking. There have been discussions of the relationship between cognitive science and design. However, no researchers have addressed the role of visual reasoning in form shaping. Shaping a form is a crucial strategy for product designers examining the possible interpretations of a design concept. In product design practice, creating a 'good' physical form involves making sense of a reasonably appropriate structure for users to interact with others and their environment during a particular human and cultural activity and interpretations of humanity, technology, business and sustainable development.

One of the main tasks of this research was to understand what product designers experience in terms of visual reasoning in the design process and how they interpret these experiences in the form of a sketch prototype or scenario prototype. The designers' perceptions of their awareness of the use of crafting technologies (spatial reasoning) in the design process and the use of different approaches to shape a specific visual form were examined. This contributes to the field of product design in two crucial areas. First, the results inform the improvement of product design process tools (e.g. CAD software and effective design education). Second, by examining closely the reasoning approaches of product designers, the appropriateness of current design approaches was analysed and inspired a new design strategy.

This research was based on my personal experience of the product design process in which a specific visual reasoning in the process of product design was identified. The comparative study of the experiences of design workshop trainers through interviews informed an ontological understanding of prototyping (visual reasoning) in product design practice. The structure and essence of the visual reasoning experiences of designers working on solving product design problems were identified. This helped to develop a useful framework for solving complex product design problems (making sense of things), illustrating the relationship between the prototyping mechanism and ill-defined design problems.

2.1.3 Overview of design workshops and processes

Design workshops focus on active and experiential learning and are short term and intensive

As mentioned in Section 1.2.3, the six levels of learning experience are generally based on a collaborative learning environment, in which a small group of people are guided to work, contribute to or perform certain tasks, problems or goals.

Brooks-Harris and Stock-Ward (1999) wrote comprehensively about the definition of workshops and developed an integrated model to design and facilitate workshops in the fine arts context. They first discussed the historical definition of ‘workshop’, which originally designated a place where things were made and sold. They inferred that when educators started to use ‘workshop’ to describe a particular type of learning environment, it referred to ‘a place where work occurs, where tools are used to accomplish this work, where things may be repaired, and where the work may result in a particular product or outcome’ (p. 3). They also presented other people’s viewpoints; for instance, a workshop has been regarded as a platform for developing competence or promoting behavioural change among participants through interactive yet problem-focused learning. Hands-on practices are used in practical and intensive interactions and small group work to apply new learning, identify and analyse problems and develop and evaluate solutions.

Brooks-Harris and Stock-Ward described the characteristics of workshops as follows: i) intensive short-term learning; ii) small group interactions; iii) active involvement; iv) development of competence; v) problem solving; vi) behaviour change as an outcome; and vii) the application of new learning. In addition, they identified five possible areas of focus: i) problem solving; ii) skills development; iii) increasing knowledge; iv) systemic change; and v) personal awareness/self-improvement. Moreover, they proposed a new definition of ‘workshop’: ‘**A workshop is a short-term learning experience that encourages active, experiential learning and uses a variety of learning activities to meet the needs of diverse learners**’ (p. 6).

In their instructional workbook, based on the definition proposed in *Webster’s New Collegiate Dictionary*, Steinert and Ouellet (2012) stated that a workshop is ‘**a usually brief, intensive educational program for a relatively small group of people in a given field that emphasizes participation in problem solving efforts**’ (p. 3). Similar to Brooks-Harris and Stock-Ward (1999), they further explained that a workshop is a time- and cost-effective educational method offering learners the opportunity to exchange information, practice skills and receive feedback in an active involvement setting. Furthermore, they suggested that the inherent flexibility and promotion of the principles of experiential learning and adult learning are the reasons why workshops are popular. Finally, a workshop can be adapted to diverse settings to facilitate knowledge acquisition, behavioural change or skills development.

A general description of the workshop design process can be structured into four phases: discover, define, develop and deliver. This framework was proposed by the British Design Council in 2005 to classify the sketches/illustrated thoughts of designers.

The designer receives and synthesises all of the information and conclusions supplied by the other three roles (businessman, engineer and manufacturer). This process of concept synthesis involves a lot of critical judgement and decision-making (reflective practitioners). Designers look for a 'form' that can connect all incomplete and independent ideas or features to frame a sense-making concept. Nigel Cross (2011) claimed that in the design process, the problem and the solution usually develop together. This explains why design happens quickly and is difficult to record, describe and transfer to other people.

2.1.3.1 Designing and prototyping as reflective practice

Creating a design theme helps designers frame a problem for which specific solutions arise immediately. Donald Schön (1983), a renowned scholar in design philosophy, identified a cognitive process of reflection-in-action as the intelligence guiding the 'intuitive' behaviour of designers in the practical contexts of thinking-and-acting, developing the theory of reflective practice.

According to Donald Schön's theory of reflective practice (1983), 'competent practitioners usually know more than they can say. They exhibit a kind of knowing-in-practice, most of which is tacit'. As explained by Nigel Cross (2011), Schön regarded the cognitive process of reflection-in-action as the intelligence that guides 'intuitive' behaviour in the practical contexts of thinking-and-acting. He described this process as a 'frame experiment' in which practitioners frame or pose a way of seeing the problematic situation during reflection-in-action. Designing becomes 'a reflective conversation with the situation', which is an interactive process that frames a problem and explores its implications while being stimulated or changed and investigates the possible solution. During the design process, 'the designer may take account of the unintended changes he has made in the situation by forming new appreciations and understandings and by making new moves. He shapes the situation, in accordance with his initial appreciation of it, the situation "talks back", and he responds to the situation's back-talk'.

As a designer and design educator, I am aware that a designer constantly modifies his/her ideas through sketching or in a single sketch to look for an appropriate solution. In my experience, as Schön observed, the first sketch or first line a designer draws will stimulate a follow-up evaluation process. A quick rectification or modification will be made simultaneously and spontaneously. In other words, the formation process of a visual form may create an iterative loop between the two worlds of the designer, and this cognitive process can be described as first-order and second-order creation. Pierce's semiology also indicated that a designer perceives the immediate sign (or the first line, curve or shape) s/he produces, which becomes an initiative to elicit the second order of signification, connotation. A new association is constructed and the designer can either accept it (i.e. correct the sketch based on this new association) or reject it (i.e. continue sketching based on the previous assumption).

Negotiating between the problem and the creative solution

As Nigel Cross argued (2011), 'design initiates novel forms. A scientific hypothesis is not the same thing as a design proposal. A speculative design cannot be determined logically, because the mode of reasoning involved is essentially abductive'.

Designers have conversations with their drawings and possibly with texts. Bryan Lawson (2006) stated that in their creative process, designers tend to explore the ideas to get more understanding about the problem rather than to focus on just finding a solution. This is referred to as the 'co-evolutionary' model of design, in which 'a series of solution states each evolving from the previous one in parallel to a series of problem states again each evolving from the previous one' are observed. During the evolution, there are 'cross-influences in both directions so potentially each evolutionary development is the product of the previous state in both the problem and solution series'.

Based on the above theories and models, I developed the diagram below to illustrate the mechanism describing the process of transformation of a design problem and solution, from a conceptual idea to a visual form taking place between two areas of mental activity of the designer. The two-order creation process of the designer (the dialogue between the designer and his/her sketch) takes place in the process based on encoding (external factor) and in the process based on decoding (internal factor).

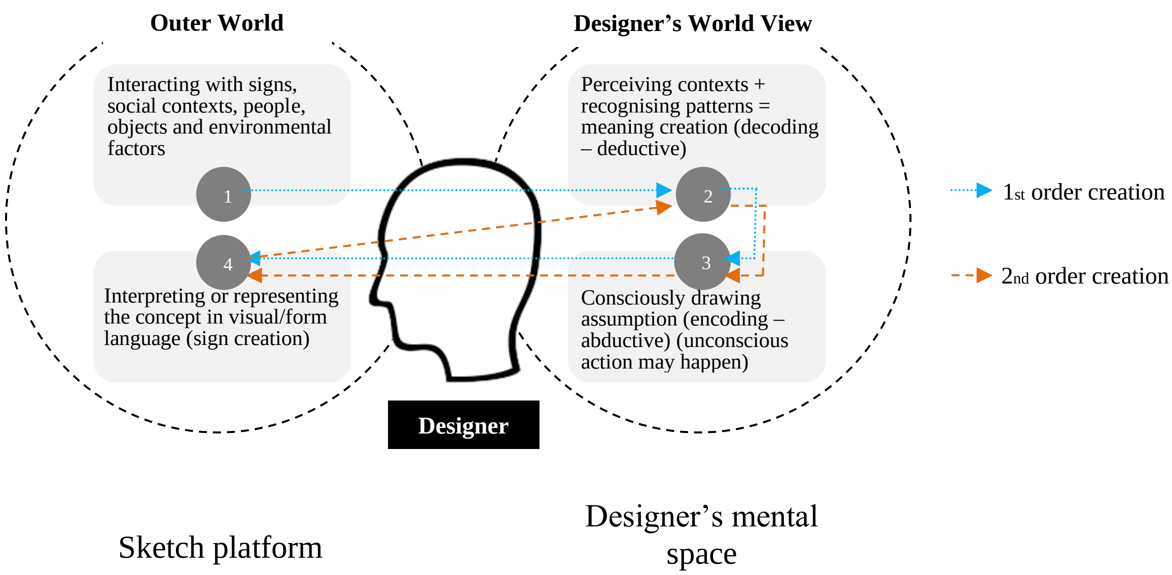


Figure 2.1 Proposed model to illustrate the designer's dialogue with visualisation tools (e.g. sketching, model making physically or virtually). For instance, the semiotic interaction and 'frame experiment' of the designer are facilitated through drawing, in which the design concept is developed in an iterative process of first and second order creation (a sketch).

Sensitivity and articulation in visual language

Designers are praised for their ability to visually represent a concept. During a complete design project, designers engage in the four phases described by the British Design Council in 2005: discover, define, develop and deliver. Various types of designers, architects, engineers or developers may share similar approaches and tools and apply specific methods or tools in their discipline. For instance, as part of a team effort to design a stool during the 'define' phase, an engineer may use the centre of gravity and apply mathematics to generate a hypothesis. A designer may draw planes and legs to visualise an idea. An engineer may search for reasonable structures and parameters. A designer may explore a new visual structure or new visual experience/language.

Of the unique approaches and tools available to designers and architects, drawing/sketching/prototyping and visual thinking are the most prominent. Drawing or model making is an advanced ability to coordinate visual/spatial mental images and manipulate drawing tools by hand. The articulation of visual elements, semantic analysis and visual syntax may also be strongly correlated with designers' visual-spatial intelligence and the coordination of fine motor muscles (manipulation of a pen by hand and fingers). This research focused on visual-spatial intelligence.

2.1.3.2 'Objectness' – The Dual nature of technical artefacts as a language bridging function and structure

The task of design is to bridge the gap between the **function** and **structure** of an artefact (Galle, 2002). Design is about processes. Kroes (2002) also called it the dual nature of technical artefacts. Technical artefacts are physical objects with a structure, but also intentional objects with a function. Bucciarelli (2002) suggested the concept of '**object world**' to describe a world with a variety of things with particular and specialised modes of representation. The concepts, ideas and relationships between the things of an **object world are constructed by its own language**, including its own unique instruments, reference texts, prototypical bits of hardware, tools, codes or unwritten rules. This is what I call '**objectness**' later in the thesis, and it goes hand in hand with the other two parameters (concreteness and situatedness) of the scope of this study on the investigation of prototype-ability in the representation of a design concept.

Bucciarelli argued that this object world language is a proper language with technical and instrumental qualities and a scientific language both elaborated and specialised, ornamented with more elements of the world. In addition, the elements of an object world language are more than words and symbols and are represented by a particular scientific paradigm. Below are the elements of the object world language in Bucciarelli's distinctive view of visual language (2002).

1- Sketch: visual language in the mind's eye

2- Drawing: language used for communication and problem solving

3- Mental image: an external design representation understood as a cognitive artefact used by designers to find and store information in the cognitive design process. This can generate mental representations and new external representations. (Bucciarelli had doubts about the 'mental representation' of designers. Instead, he felt that mastering the language of sketching and modelling is more relevant to explaining the **situation of the design process**.)

The way people 'see' things

Bucciarelli further argued that the language used is problematic, as different participants may have different interpretations. He claimed that some strictly rational instrumental methods can be used to reconcile differences between participants. This may be achieved by translating one proper language into another, and a common measure to compare them should be established. He stated that 'here "see" is to be understood in the sense of "interpret"'.

Design language as artefact connects conceptual idea and physicality

Bucciarelli (2002) explained that the linguistic elements of artefacts are not static but active; they are shaped, specialised, reformed and extended, and provoke new thoughts and confirm conjectures. Claims regarding the counterfactual nature of design rely largely on the creation of different types of design languages, for instance the aforementioned 'sketch', 'physical mock-up' or 'chart or information graphic'. Bucciarelli concluded that language enables designers to connect thought and object, function and structure, and that design language exists between thought and object.

Kroes (2002) further elaborated on the nature of design from a functional-intentional perspective and a structural-physical perspective. I argue that both physical and symbolic functions and physical and symbolic structures exist. Visual language (function) can generate various dimensions of perceived meaning, such as the functionality of a design, symbol or interface that enhances usability and/or satisfaction.

Visual language (structure) contributes to the structural quality of a design, such as its affordance or ergonomic performance. Combining the qualities of the function and structure of a design contributes to the categorical idea of the product (e.g. a platform supported by four legs that enables a man to sit can be called a 'chair') and the overall concept and quality of a design. In addition, making sense of this 'design language' suggests an appropriate or ideal integration of specific functions and structures where innovation takes place.

To understand the complex process of making sense of 'design language', I argue that prototyping is the key mechanism that helps designers make sense of concepts by manipulating visual elements as a type of reasoning to link the function and structure of a proposed artefact or design.

2.1.3.3 Rowena Reed Kostellow's objective science on the structure of visual relationships

Hannah (2002) systematically collected pedagogical approaches and ideas regarding the appreciation and manipulation of abstract visual elements proposed by Rowena Reed Kostellow in her series of exercises with other pioneers at Carnegie Tech (now Carnegie Mellon University) and Pratt Institute since 1934, such as line, plane, colour, form, structure and volume. In 1936, Carnegie Tech produced the first graduates in industrial design in the US. Kostellow used her method to train the first generation of design educators in the US and shape American design.

In his review of Hannah's book (2002), the famous industrial designer Tucker Viemeister stated that Kostellow was 'a fantastic teacher who was able to help us see the importance of both the tinniest subtleties and the grandest gestures'. Kostellow was sensitive to visual language and her work influenced most fundamental training methods in industrial design.

'Pure, unadulterated beauty should be the goal of civilization!' stated Rowena Reed Kostellow (Viemeister, 2002). From what I observed from the case studies of form in the book, ‘unadulterated beauty’ referred to simplicity, sophistication and concern for the continuity of a form.

The philosophy of Kostellow and her colleagues fostered the principle of visual relationships, exploring the objective science of visual relationships through a series of exercises to connect students’ intellectual understanding with their physical eyes and hands (hands-on or mind-body experience). Viemeister commented that the objective of the principle is to make the elements ‘work’, not what they ‘say’. This non-subjective judgement is a constructive method of studying how people ‘read’ objects. It avoids the problem of what the content ‘feels like’, which is a matter of subjective judgement. This method helps build the legitimacy of visual-spatial reasoning. As Viemeister pointed out, most people find it easy to read symbolic signs and literal messages, but they do not consciously see abstract relationships between forms, colours and textures. In fact, the media and structure of communication with the composite of abstract visual elements carry meaning and convey real sensuous feelings. This aligns with Ingold’s argument (2011).

According to Dr William Fogler (Viemeister, 2002), another teacher at the same school, ‘industrial design is about exactly what is there. The forms of industrial design are direct support for experience: the shape the conduct of our days: they structure the experience of being alive now’. I find this statement still relevant today, as it claims that the product form can shape the behaviour and culture of users. People’s senses and values are affected by the artefacts they interact with in a situated environment. Kostellow and others believed that visual experience can be analysed through seeing abstract relationships and this ability can be taught and transferred to other related fields. Kostellow discussed the reasoning process of abstract visual elements: ‘the abstract relationships express the relation of the parts to the whole apart from any concrete or material embodiment. They reflect the direct visual experience of the thing, how forms and spaces and movements “speak” to one another’. In other words, she emphasised one of the essential tasks of designers: to formulate a design with great clarity and objectivity through visual literacy, manipulating the relationships between forms, spaces and movements projected by the entire visual structure.

Kostellow's most sophisticated idea about visual literacy was her concept of reasoning the composition of 3D objects: the relations between the dominant, subdominant and subordinate parts of an object. By introducing the core approach to identify the implied axis of a single form, designers can better identify and manipulate the relationships between various abstract and complex visual elements in a single object. A complete design can be achieved by knowing and applying this rule, and perceiving the language of an object as a whole is the key to understanding its meaning.

Organisational forces – Quasi-physics

Kostellow emphasised the awareness of space. She further elaborated on the ability to manipulate abstract forms 'to develop an understanding of the elements of design, of structure, of the organizational forces which control them, and an ability to apply this knowledge to a variety of situations in designing for self-expression or for industry'. It is worth focusing on what Kostellow described as the 'organizational forces', such as balance and tension, that constitute the visual relationship between the elements. Indeed, this emphasises the public's experience of the force or tension implied in the visual relationship between at least two surfaces or elements or between positive and negative spaces, for example. It offers an important perspective on and contribution to designing 3D structures (product, interior and architecture). In my design practice, my designer eyes see similar forces that follow the laws of physics – a type of quasi-physics. In addition to visual tension, there are visual weight, speed and momentum. In conclusion, a sketch or prototype can be considered a quick representation of a concrete concept offering a sensory experience with a certain sense of physics, stimulating further evaluation or trial and error in the early phase of a design project.

2.1.4 Visual-spatial intelligence and visual thinkers

2.1.4.1 Definition of visual-spatial reasoning

If we assume that most product designers are visual thinkers, their visual thinking pattern influences how they reason.

Howard Gardner (2011) proposed eight types of intelligence in his book *Frames of Mind: The Theory of Multiple Intelligence* in 1983: musical-rhythmic, visual-spatial, verbal-linguistic, logical-mathematical, bodily-kinaesthetic, interpersonal, intrapersonal and naturalistic. He later suggested a ninth form of intelligence: existential and moral (Smith, 2002).

Spatial intelligence (or visual-spatial) is closely related to the ability to reason and manipulate visual elements in people's mental space. As Gardner proposed (2011), it involves people's ability to explicitly create a mental image: 'Central to spatial intelligence are the capacities to perceive the visual world accurately, to perform transformations and modifications upon one's initial perceptions, and to be able to re-create aspects of one's visual experience, even in the absence of relevant physical stimuli'.

2.1.4.2 Visual thinkers

Whereas auditory sequential thinkers tend to advance their learning sequentially, visual thinkers tend to jump into different contexts to gain a holistic understanding of a given topic. This type of learning mode is unique to people who are sensitive to visual elements/language.

Lateral thinking blends well with visual thinking

Visual materials, such as graphic images, colour and texture, can be composed in a very open and creative way. They differ from verbal elements, which must be formed in a logical and sequential way to make sense of them. The characteristic of visual thinking aligns with the concept of 'lateral thinking' proposed by Edward de Bono in 1970 (2009). De Bono (1970) argued that the traditional 'vertical thinking' education model is not the only possible form of effective thinking. He differentiated two main thinking modes: vertical thinking is selective, while lateral thinking is generative. He stated that lateral thinking is necessary for the self-maximising memory system to enhance creativity. As he suggested, 'rightness is what matters in vertical thinking. Richness is what matters in lateral thinking'. Lateral thinking is useful for opening up different pathways and generating as many alternative approaches as possible.

De Bono further elaborated that vertical thinking is an analytical, sequential and finite process, while lateral thinking is provocative, can make jumps and explores probability. In the vertical thinking process, one must be correct at every step, which is not the case for lateral thinking. This highlights the nature of lateral thinking, which is part of abductive reasoning and an important way of thinking in design reasoning.

Visual thinking as visual cognition – A type of mental operation

Rudolf Arnheim (1969) contributed to the theory of visual perception. He focused on visual perception as a cognitive activity. He argued that an artistic activity is a form of reasoning in which perceptions and reflections on visual forms are inextricably linked. With a grant to study visual factors in concept formation, Arnheim's book *Visual Thinking* reported astonishing results. He discussed the existence of the intelligence of visual perception and argued that 'cognitive operations called thinking are not the privilege of mental processes above and beyond perception but the essential ingredients of perception itself'.

For Arnheim, visual thinking is visual perception. This cognitive operation includes active exploration, selection, grasping the essentials, simplification, abstraction, analysis and synthesis, completion, correction, comparison and problem solving. In addition, it involves combining, separating and putting into context. He described all mental operations as 'cognitive'. In other words, visual thinking is an active concern of the mind (not a passive recording of stimulation material).

Arnheim identified three functions performed by images to clarify and compare the different relations of images with their referents. These three functions are pictures, symbols and signs, which are not different types of images. Arnheim differentiated images as follows.

- An image serves merely as a sign to the extent to which it stands for a particular content without reflecting its characteristics visually.

- Images are pictures to the extent to which they portray things located at a lower level of abstractness than they are themselves.
- An image acts as a symbol to the extent to which it portrays things which are at a higher level of abstractness than is the symbol itself.

This perspective on the three functions of images is a type of cognition that affects the way people perceive ideas and reasoning.

Unique capacity of people – Visualisation

Colin Ware (2005) emphasised the importance of visualisation for people, contributing to cognitive thinking. He stated that thinking involves a constant interplay between new patterns and old patterns, which can come from the external world (seeing) and the inner mind (mental image). He added that the term 'visualisation' previously referred to the mental images people formed when thinking, while now it often refers to a graphical representation of data or concepts. Graphs, diagrams and illustrations have become important visual thinking tools. He stated that perceiving is an active process requiring skills. People search for what they need through their eyes and make visual queries whenever they search for visual information. To demonstrate his argument, he quoted Donald Norman (1993) as follows.

> The power of the unaided mind is highly overrated. Without external aids, memory, thought and reasoning are all constrained. But human intelligence is highly flexible and adaptive, superb at inventing procedures and objects that overcome its own limits. The real powers come from devising external aids that enhance cognitive activities. How have we increased memory, thought and reasoning? By the invention of external aids: it is things that make us smart.

2.1.4.3 The nature of visual thinking

Ware (2005) distinguished between visual thinking and language-based thinking. He proposed that a sign-based language consists of a fundamentally visual mode (related to symbolisation) and a fundamentally auditory mode (related to logic). Language is a socially developed system of shared symbols and grammar, called learned symbols. However, it is important to remember that what Ware described as the basis of visual thinking is pattern perception, not learned symbols. People's understanding of meanings through pattern recognition does not come from social conventions. In fact, Ware reminded us that…

> "…our perceptual machinery comes partly from evolution and partly from visual experiences as we interact with the world; in other words, our pattern perception is partly innate and partly learned. When we see designed graphical patterns, objects and connections are perceived using this combination of perceptual processes. Patterns convey meaning in ways that are not arbitrary and not socially determined … visual designs are almost always hybrids; they have aspects that support visual thinking through pattern findings, and they have aspects that are conventional and processed through the language system" (2005, p. 131).

He also suggested that visual logic is the logic of patterns, objects and spaces. This includes structuring two-dimensional information via pattern recognition (contour, texture, spatial layout, semantics), colour (principles, sequences, semantics) and visual space and time (perception of depth, motion, three-dimensional concept, affordance, orientation and semantics).

2.1.4.4 Anthropological perspective – Visual anthropology

Drawing is the embodiment of ways to make, observe and describe things

Tim Ingold and a group of anthropologists proposed that **drawing** is a **unique approach** that brings together **ways to make, observe and describe things** (Ingold, 2011). They discussed this thing-centred perspective and the embodied cognition and movement of a line. Part of their study explored the generative dynamics of skilled practitioners who respond to moment-by-moment variations in the conditions of their environment. They argued that practitioners participate in the creative process by using drawing as a method and technique to reconnect observation and description to the movements of improvisatory practice.

Visual is 'touchable'

Rupert Cox (Ingold, 2011, p. 70) also mentioned that practitioners (e.g. artists or craftsmen) can **feel the haptic sense through vision** and that **touch can be as 'optical' as vision**. This is consistent with the importance of surface finishing in a product for designers: information about the surface of a product (e.g. colour and texture) conveys its sense to designers and users, such as haptic sense or touch. This suggests that sketching or the process of form-giving is a continuous dialogue between the designer and the representation. It is a cognitive process of reasoning, in which designers use drawing tools to argue for the appropriation of a product or explore its possible structure and meaning. It is a case of embodied cognition, as behavioural intelligence emerges from the interplay between the body, the brain and the environment.

Sheets-Johnstone (Ingold, 2011, p. 117) described in detail the quality of hand movement when writing or drawing, which includes the cognitive processes of duration, rhythm, varying tempo, pauses, attenuations, pitch and amplitude. This clearly explains the complexity of a line – a 'lively' line. In other words, drawing a line can express complex emotional qualities.

According to Mathewson (1999), visual-spatial thinking includes the following elements.

> Vision – using the eyes to identify, locate, and think about objects and ourselves in the world, and imagery – the formation, inspection, transformation, and maintenance of images in the mind's eye in the absence of a visual stimulus. A spatial image preserves relationships among a complex set of ideas as a single chunk in working memory, increasing the amount of information that can be maintained in consciousness at a given moment. Vision and imagery are fundamental cognitive processes using specialized pathways in the brain and rely on our memory of prior experience. Visual-spatial thinking develops from birth, together with language and other specialized abilities, through interactions between inherited capabilities and experience. Scientific creativity can be considered as an

> amalgam of three closely allied mental formats: images; metaphors; and unifying ideas (themes). Combinations of images, analogies, and themes pervade science in the form of master images and visualization techniques.

2.1.4.5 A case of visual thinking in design education

Robert McKim (1972) developed a course in visual thinking at Stanford University and in his book *Experiences in Visual Thinking* in the 1960s and 1970s. This was the first book devoted to the strategy of visual thinking for design innovation. His students lacked imagination or creative ideas during creative exercises. Therefore, being able to educate them in 'seeing and imagining' became the main goal of his book. He drew attention to the fundamental relationship between idea-sketching and imagination to forge 'thinking operations' or 'strategies'. He described idea-sketching as an active model of the frequency of introspective accounts of the 'mind's eye' imagery of designers in the literature on creativity and ways to invigorate and direct inner sensory imagery. He sought to integrate seeing, imagining and idea-sketching and used the term 'visual thinking' to describe the interaction of ideation processes.

McKim argued that visual thinking is a 'meta-strategy', which is a fundamental mode of thinking (a major alternative to other modes, such as verbal thinking). He explained that visual thinking is composed of three activities: idea-sketching, seeing and imagining.

What is visual thinking? McKim first emphasised that for humans, the concept of thinking is not constructed under the mind-body dichotomy (separating thinking from feeling). Instead, from a neurological point of view, thinking is generated by the entire nervous system (not just the brain). He stated that we know thinking through personal experiences, and thus the vitality of our thinking is intimately related to the state of our physical health.

McKim identified three categories of design processes: seeing, imagining and idea-sketching. Under seeing, he examined externalised thinking, refocusing seeing through drawing, pattern-seeking, analytical seeing, proportions and seeing cues to form and space. Under imagining, he addressed the mind's eye, visual recall, autonomous imagery, directed fantasy, structures and abstractions and foresight and insight. Finally, under idea-sketching, he listed a wide variety of visual thinking strategies, demonstrated that sketching is a tool of visual thinking giving rise to ideas of an iterative nature and discussed the importance of graphic language proficiency in developing visual ideas and the use of strategies to stimulate idea-exploration.

2.1.5 Visual-spatial reasoning in prototyping

Visual-spatial reasoning (or visual reasoning) is associated with non-verbal reasoning to understand and analyse visual information and solve problems. The term describes the capacity of the human intelligence (ability and sensitivity) to recognise, memorise, compare and reason about visual images (images or symbols in the outside world and mental image) to coordinate and interact with the body and the world. Several researchers have identified and described visual reasoning as a unique conceptual thinking process of designers (Goldschmidt, 1994; Oxman, 2002).

A good example of the daily use of visual-spatial reasoning is the Career and Employability Service website of the University of Kent. The site offers diagrammatic and spatial reasoning tests to evaluate users' spatial intelligence, including identifying relationships, similarities and differences between shapes and patterns, recognising visual sequences and relationships between objects and remembering these elements. Testing diagrammatic reasoning (also called abstract reasoning) provides a measure of general intelligence. The processes of representing diagrams, understanding logical rules and process diagrams and identifying causes are evaluated. Abstract reasoning is used to cope with complexity and novelty. Spatial reasoning tests can predict the ability to work with complex scenarios. They involve the ability to mentally rotate the two-dimensional representations of three-dimensional shapes.

Visual-spatial reasoning is identified as a type of thinking that plays a significant role in **prototyping,** such as mentally constructing 2D or 3D structures or changing visual elements in one's mind. Some tools, such as sketching, drawing diagrams, manipulating physical objects (e.g. proving an idea by creating a mock-up) and building virtual computer models, are always used to facilitate visual reasoning. Studying visual-spatial reasoning can highlight the cognitive side of design, including its societal, cultural and technological dimensions.

Prototyping is the product of visual-spatial reasoning. **Prototyping** has **six roles,** indicating the importance of its contribution to participatory design approaches and design development. Sanders and Stappers proposed that prototypes can perform the following functions (Sanders & Stappers, 2014, p.6):

i) **Evoke a focused discussion in a team**, because the phenomenon is 'on the table'.
ii) **Allow testing of a hypothesis.**
iii) **Confront theories**, because instantiating one typically forces those involved to consider several overlapping perspectives/theories/frames.
iv) **Confront the world**, because the theory is not hidden in abstraction.
v) **Change the world**, because in interventions it allows people to **experience a situation** that did not exist before.

2.2 Contextual approaches to visual-spatial reasoning

Object is symbolic

According to O'Neill (2008, p. 144),

> we live in a world that has been vastly altered by our cognitive abilities such that we inhabit not only the empirical world of physical entities but also the world of sign systems, which are a direct result of our cumulative interactions with the world (and each other) over time. Thus, the relationship between the subject and the object is dealt in a pragmatic way, where external phenomena are experienced as signs that are meaningful to the organism and there is no separation of the two.

2.2.1 Semiology in design

2.2.1.1 People's world view is constructed by signs

Semiology, the study of signs, was adopted as a fundamental framework for formulating the research hypotheses and developing the research questions (Erlhoff & Marshall, 2008). Most current applications of semiology are extensions of the work of the American philosopher Charles Sanders Peirce (1839-1914) and the Swiss linguist Ferdinand de Saussure (1857-1913).

> **What is sign?**
> A motion, gesture, or bodily action by which a thought is expressed or a command or a wish is made known; b: signal; c: a unit of language (as word) that means, stands for, designates, or denotes something to an interpreter-compare icon, index, symbol; d: one of the members of a methodical set of gestures used to represent language directly word by word or letter by letter. Extracted from *Webster's Third New International Dictionary*.

Peirce identified **three essential modes of signification** in every sign: **iconic**, **symbolic** and **indexical**.

- The **icon** relates to its referent by means of resemblance; it looks, sounds, smells, feels, or tastes like what it represents.
- The **symbols** are arbitrary signs; they relate to their referent only because an interpretive community agrees on the relationship. Language is largely a symbolic system.
- The **index** evokes its referent by a physical trace. A footprint, for instance, signifies a person's presence indexically. Most signs relate to their referent by some combination of these three modes.

He also described the functioning of signs in terms of a three-part system. The form of representation (or representamen) works in relation to its referent and to an interpretant, someone who reads, sees and hears the sign. Iconic, indexical or symbolic representations are understood as different interactions between these three elements.

Saussure described the functioning of the linguistic sign, roughly equivalent to Peirce's symbol. The Saussurean sign is composed of two parts: a **material form, the signifier**, and a **representational aspect, the signified**, which is the referent designated by the signifier. Saussure noted that a sign system can only work if one signifier can be differentiated from another. A sign is therefore defined by difference.

Barthes (1973) was influenced by Saussure, who postulated that the science of signs, or semiology, can be categorised as one stream of science that studies the nature of the sign of things, the development and logic of changes in the sign, the different meanings of the sign and its relation to human activities.

2.2.1.2 Visual material/culture as a form of language

Applying Saussure's terms to visual material, Barthes described how culture-based conventions can become languages used to read design. Barthes made a distinction between the direct and denoted meaning of an object and its connoted meanings, the symbolic resonance of an aspect of the object in the system of cultural conventions, or codes. He noted that an image or object can imply a set of connoted messages based on the coded invoked by the observer. Other authors have analysed typography in a similar manner: the linguistic meaning of a word is its denoted message, and its graphic characteristics – the allusions implied by the typeface, layout, and so on – is its connoted, or coded, message. Barthes also proposed that the fields of design, such as fashion, can be conceived as languages, adopting a Saussurean distinction between language as a system and speech as the creation of signs within it. The combination of individual items, such as a suit of clothes, can thus be discussed as an utterance in the sign system of fashion.

2.2.1.3 Semiology of designer thinking and design object

People live in a symbol-filled world and interact mainly through communication and mediation via symbolic means. Language is a system that has meaning and connects the people, objects, events and ideas in our lives, forming our world view and value system. Designers are both the recipients of the world of symbols and stakeholders who participate in the creation of the sign/symbolic world.

Many researchers have used Peirce's categories of signs as a model for interpreting design objects. The iconic meaning of an object is related to its formal or stylistic similarity to other objects – natural or man-made – or its metaphorical properties. The physical properties of the object can be considered as the indexical signs of the materials and conditions of its production, and the object's function, or any of its formal qualities, can have a symbolic meaning, inasmuch as these qualities have arbitrary meanings defined by conventions among the object's audiences. Another line of inquiry further breaks down the symbolic value of the object into a denoted meaning based on the recognition of the object's function and connoted meanings based on the affective values associated with the object itself and its formal qualities.

According to Saussure (on the linguistic sign), the dyadic relation between signifier and signified is essentially 'arbitrary'; that is, there is no direct connection between shape and concept and it is motivated only by social conventions. Unlike Saussure, Peirce defined the sign as a triadic relation as 'something that stands for something, to someone in some capacity' (Danesi & Perron, 1999). The sign can be divided into icon, index or symbol depending on the type of relationship.

A semiological sign, as a linguistic sign, is a compound of signifier and signified (e.g. the green human figure indicates 'cross' in the Highway Code), but it differs in the level of its substance. Many semiological systems (objects, gestures, pictorial images) have a substance of expression whose essence is not to signify. Often, they are objects of daily use, used by society in a derivative way to signify something: clothes are used for protection and food for nourishment, even if they are also used as signs. Barthes (1973) called these semiological signs of utilitarian and functional origin 'sign-functions'.

Here we need a second-order language, which is in no way identical to its first functionalisation and corresponds to a second semantic institutionalisation, that of the order of connotation. Therefore, the sign-function has an anthropological value as it is the very unit in which the relations of the technical and the significant are woven together.

The sign itself has no meaning until the reader processes it. The second level of the signified brings a meaningful sign/concept to the reader: signification. Semiologists have shown that the phenomenon of the sign has no motivation. Instead, once a person becomes a subject, s/he will classify/operate a reasoning process: establish the sign's phenomenon in a meaningful sign system and reach a common agreement with others/the community.

Table 2.1 First and second orders of sign theory.

3 Connotation	Signifier: rhetoric			Signified = ideology
2 Denotation: Metalanguage	Signifier	Signified		
1 Real system		Signifier	Signified	

2.2.2 Symbolic meaning in product design

Design is making sense of things. Krippendorff (1995) claimed that because of its human-centred focus, a good design should be able to communicate with users and stakeholders. Designers place more emphasis on how artefacts should function to generate meaning for people, or conversely, on how people perceive artefacts or are affected by them. From this perspective, a design should be able to communicate with users or consumers and interact with them under certain presumptions or conditions. Therefore, this is a vital topic in product design and product designers pay more attention/are highly aware of the creation of meaning, which should be reflected in a typical design project/thinking process.

2.2.2.1 Product semantics

According to Krippendorff and Butter's definition (2008), product semantics is the study of the symbolic qualities of man-made forms in the context of their use and the application of this knowledge to industrial design. It refers to a systematic inquiry into how people attribute meanings to artefacts and interact with them accordingly, indicating a vocabulary and methodology for designing artefacts based on their meanings for their users and the communities of their stakeholders. Product semantics helps designers to be aware of the symbolic processes at four levels, namely 1) product identification, 2) self-evident operations, 3) explorability of forms and 4) coherence with the symbolic context.

2.2.2.2 Product pragmatics

In design research, the study of visual grammar has been poorly defined and often neglected. The majority of efforts devoted to similar research have focused on other perspectives, such as art history, or on the formal and aesthetic description of composition. As mentioned by Gunther Kress (2006), little attention has been given to the meaning of regularities in the way image elements are used. This is the subject of grammar, which requires explicit or systematic analysis as the principle of linguistic structure. Visual structures can be evaluated through interpretations of experience and forms of social interaction and can also be expressed linguistically.

Suppose that the visual experience of a product design is similar to a written sentence constructed from basic units of natural languages – sentences, phrases and words. These units can create a larger pattern (e.g. a meaningful dialogue) and generally, there are general rules that govern the construction of sentences in a particular culture or community. Therefore, is there a rule or principle that can govern the construction of a product design or three-dimensional functional forms? Some researchers have proposed visual typologies and design principles to answer this question. To answer this question, this research project collected, compared and explored a comprehensive understanding of visual syntax.

2.4 Cognitive approaches to visual reasoning and prototyping

The traditional outcome of product design (in the area of product designers) is to improve functionality, usability and pleasurable experience (e.g. make the user smile, generate interest; Cila, Hekkert, & Visch, 2014; Jordan, 2002).

In conventional design education, product design training emphasises the manipulation of form language (e.g. style building). Thus professional product designers treasure this skill as their core ability. Nevertheless, although designers understand that simplicity and practicality are the best design directions, many designers spend most of their time dealing with aesthetics (changing proportions, colour, texture, etc.) instead of demonstrating the function of a product or the mechanical performance of a design. We must pay attention to the phenomenon of the current design philosophy: product and system designs (in particular consumer products and services) tend to meet people's emotional needs and expectations rather than their physical functional needs. Clearly, designers prefer to bypass the technical problems of a design and expect another expert (e.g. a mechanical or manufacturing engineer) to solve these technical challenges. It is even more noticeable with more complex product designs, such as smart home system and product design. To identify and differentiate between product designers and product engineers, the importance of designers lies in their demonstration not of creativity in product function, but of creativity in the aesthetic experience (a beautiful and complex mix of new functions, new meaning creation, new business models and production breakthrough). Designers tend to gravitate towards redefining or generating a creative dialogue with users and stakeholders through the format, appearance and interactions offered by a product. This leads to the conclusion that the product form-giving technique is the most significant and useful skill (a thinking and practical skill) recognised and appreciated by designers.

2.4.1 Sketching and ontology of the form-giving process

2.4.1.1 Ontological understanding of the form-giving process of design

Ontology building is one of the forms of the knowledge capture process. The subject of ontology is the study of categories of things that exist or may exist in certain domains.

In addition, ontology is a catalogue of the types of things that are supposed to exist in a domain of interest. It is a similar method to building taxonomy trees that can describe the knowledge of objects in the real world and associations between people, places, machines, events, etc. Ontologies provide the context in which information is transferred between two agents.

In this study, a visual-spatial reasoning framework for product design and a set of questions and experiments were developed to facilitate design sketching to generate a product concept. The results were examined and analysed in an attempt to correlate individual processes and modes of design thinking, such as visual or textual exploration of ideas, metaphor application, and inductive, deductive and abductive reasoning.

2.4.1.2 Introspective experience in design thinking – An experiential approach to learning by working

McKim (1972) developed a comprehensive exercise in his design thinking class for his students at Stanford University to experience visual thinking. He explained that this learning by working approach can help participants observe their own mental processes as they attempt to solve a problem related to the adoption of visual thinking skills. He stated that it is difficult to focus simultaneously on introspection and problem solving during visual thinking work. He pointed out this idea by citing Charles Osgood: ‘Only the effects of thought, not the process itself, can be observed. A man cannot lift himself up by his own bootstraps: neither can be observed that which is doing the observing’. Conversely, I propose that by sketching a detailed record of thinking in one’s mind and with the great awareness of the analytical mind, we can review and analyse in detail our own sketches to generate a high quality introspective analysis of our own thinking process.

To understand the design process from a first-hand experiential perspective, I explored the operation of design through the detailed recording of a design exercise (designing a vase using sketching as a tool to externalise a conceptual idea). The process was carefully examined in terms of product form-giving and logic (for more details, please see Appendix One).

2.4.1.3 Three types of operation model

During design creation, I realised that I was thinking both through sketching and with my mind's eye. After the design and evaluation, I identified a combination of the three modes of thinking presented below (Table 2.2). The table shows that the concept- and form-shaping processes are iterative/looping activities that can involve endless exploration, modification and conceptualisation.

Table 2.2 Three modes of thinking in prototyping.

Modes	Actions in prototyping
A- Thinking process based on pattern recognition	Searching for possible object categories and taxonomies of a design inside and outside the domain of this design
B- Thinking process based on exploration	Exploring different combinations of taxonomies and visual structures, including 1- Physical elements (e.g. line, form, texture, material, colour, etc.) 2- Functional features (e.g. bottle cap, bottle neck, bottle body, etc.) 3- Construction logic (e.g. wide mouth + short bottle neck + wide bottom)
C- Thinking process based on sense-making	1- Identifying a meaningful/'making sense' design concept using all possible ideas generated in Modes A and B. 2- Modifying Modes A and B once a meaningful idea has been identified in Mode C and making new judgements or adjustments to all modes

The three modes above based on my personal design experience are consistent with the seven types of visual thinking operations suggested by Robert H. McKim in his book *Experiences in Visual Thinking* (1972).

i. **Pattern-seeking**: Operation of closure by i) filling in; ii) finding; iii) matching; iv) categorising; v) pattern completion.
ii. **Visual memory**: i) Memory for designs.
iii. **Rotations**: i) Inverse drawing; rotating dice.
iv. **Orthographic imagination**: Cutting through a solid object and viewing the resulting cross-section. i) From another viewpoint.
v. **Dynamic structures**: Manipulating structure of three-dimensional object. i) Folded pattern; ii) knots; iii) pulleys (motion in visual-spatial operations is likely affected by kinaesthetic (muscle) imagery).
vi. **Visual reasoning**: i) Spatial analogy/visual deduction (logical reasoning in visual means); ii) visual induction.
vii. V**isual synthesis**: The whole is a new identity that is more than the sum of its parts.

Obviously, McKim's types of visual thinking operations can be categorised into the three processes of design thinking I observed during the design exercise.

Table 2.3 Three modes of conceptualisation in prototyping and corresponding visual thinking approaches.

Modes	Actions in prototyping	McKim's seven types of visual thinking
A- Thinking process based on pattern recognition	Searching the possible object categories and taxonomies of a design inside and outside the domain of this design	i-**Pattern-seeking** ii-**Visual memory**
B- Thinking process based on exploration	Exploring different combinations of taxonomies and visual structures, including 1- Physical elements (e.g. line, form, texture, material, colour, etc.) 2- Functional features (e.g. bottle cap, bottle neck, bottle body, etc.) 3- Construction logic (e.g. wide mouth + short bottle neck + wide bottom)	ii-**Visual memory** iii-**Rotation** iv-**Orthographic imagination** v-**Dynamic structures** vi-**Visual reasoning** vii-**Visual synthesis**

C- Thinking process based on sense-making	1- Identifying a meaningful/'making sense' design concept using all possible ideas generated in Modes A and B. 2- Modifying Modes A and B once a meaningful idea has been identified in Mode C and making new judgements or adjustments to all modes	i-**Pattern-seeking** ii-**Visual memory** vi-**Visual reasoning** vii-**Visual synthesis**

2.4.1.4 Application of visual-spatial thinking at different stages of design

A designer will adopt different visualisation tools and methods in different modes and types of design, including prototyping (sketching and model making). Sketching on paper and computerised tools are the main platforms for creating a dialogue between the mind's eye of designers and others. Sketching is the most practical approach and requires relatively little professional training.

Below, I further describe the meaning of design thinking and visual-spatial thinking for designers.

Design thinking is a process of searching and exploring 'meaningful structures'

The form-shaping process works in a similar way to the composite meaning of verbal language. Designers create a dialogue between their design and that of others in the sense of language: a speechless interpretation or argument (personal intrinsic communication) in which associations of signification, representation, reference and meaning are constructed by assembling and disassembling different contexts, such as cultural and visual meanings, technologies and humanity.

Visual thinking as a tool to understand the background, what to collect and how to connect

To approach a new topic of design, designers may construct a simple mind map or sketches to brainstorm different aspects, demonstrating an attempt to **collect and**

connect direct or indirect contexts related to the subjects studied and to understand the topic in a broader picture.

Mind mapping as a visual thinking tool to review what is done and what is not

To get a clearer picture of what they are doing, designers usually create a mind map before, during or even after confirmation of the final design direction. A mind map can help designers 'release' the 'rigidness' of a design concept. It is also used to evaluate a design in other contexts. Some areas of design problems that have not been addressed during the initial design phase can be implemented. Thus, with the exception of sketching the product form, mind mapping is a tool that works closely with visual reasoning. It is important in design, especially for novice designers who construct a comprehensive conceptual map with visual and contextual information of their study subject to launch an **informative and liberal network** at the beginning of each design process. The process of collecting and connecting is a fundamental step in **generating design hypotheses or assumptions** at the beginning of the idea development phase.

Sketching to understand the archetype of an object and conceptual understanding of the meaning of an object in terms of aesthetics, structure and technology

Sketching supports visual thinking in different dimensions.

A quick sketch of an object can come from the designers' subconscious and be considered an archetype of a particular type of product. The designers' **awareness of a design archetype** is very important for choosing an innovative solution in the later stage of the design process. It can inform designers that the archetype is a cliché (negative choice for differentiation from other bottles) or an icon (positive choice for a visual statement in a relevant context). In addition to collecting information and concepts, the mind map allows designers to quickly explore form making strategies from different perspectives:

i. Geometric form.
ii. Organic form.
iii. Mixing geometric and organic forms.

iv. Manipulation of the form through proportions.
v. Application of materials.
vi. Application of different finishes.
vii. Application of colour.

2.4.2 Prototyping in abductive reasoning

To understand the general flow of the design reasoning process, the relationships between the four 'D' design process (mentioned earlier) and the three types of reasoning are illustrated in the diagram below, which maps design processes and reasoning activities to describe a general design development procedure, objectives and reasoning actions. In the process, the three types of reasoning (induction, abduction, deduction) follow a sequential order from 'discover' to 'deliver'.

In the general design process, the early phase concept prototype (such as sketching or a simple mock-up) is operated using abductive reasoning, in which the 'define' stage and the 'develop' stage usually overlap, as shown below. Occasionally, prototyping can be carried out during the 'discover' stage to identify potential design problems and opportunities.

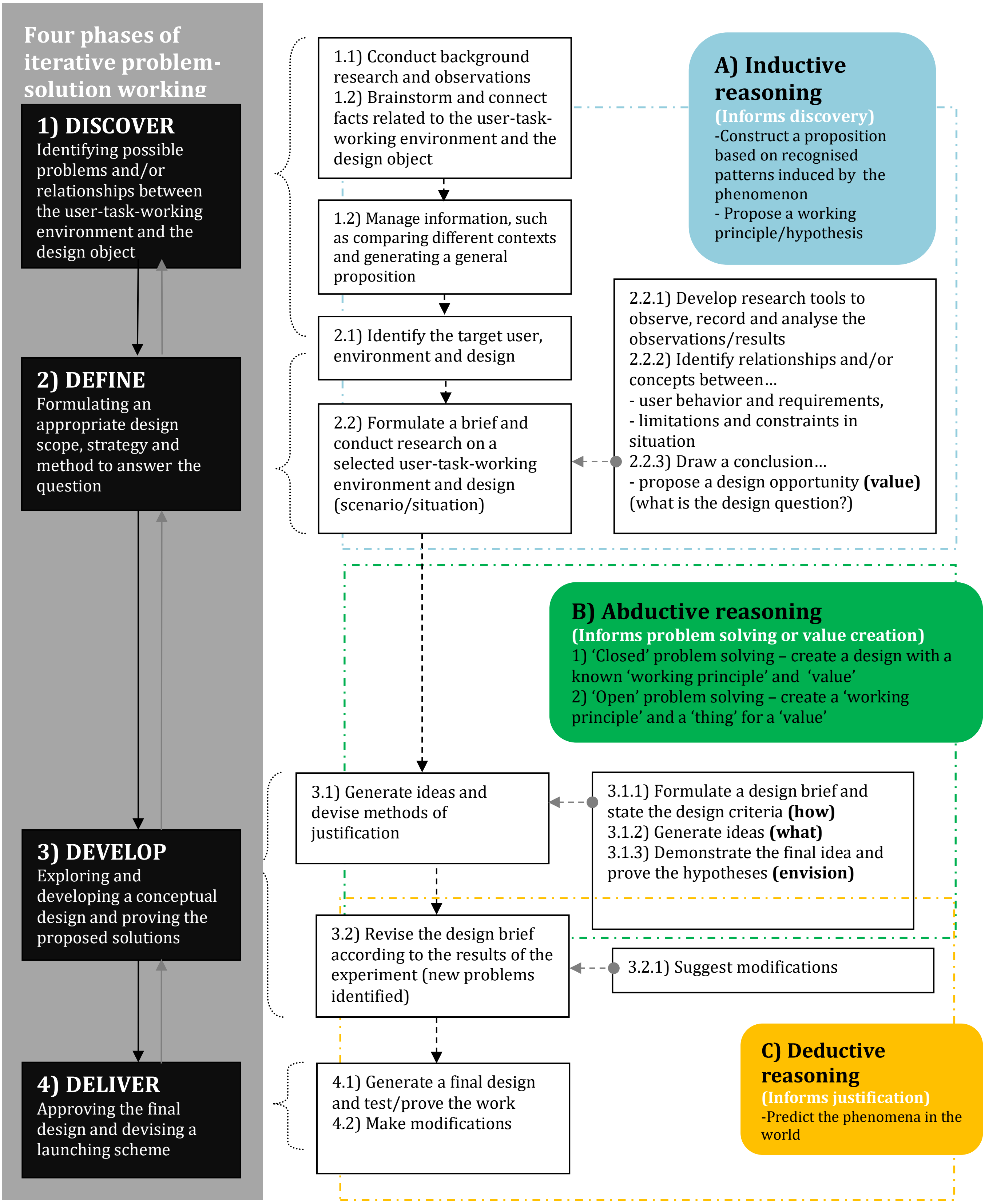


Figure 2.2 Mapping of the design process and reasoning.

2.5 Epistemological approach

The epistemological approach of this research was based on the scaffolding of constructionism, itself derived from Jean Piaget's constructivism. Seymour Papert's constructionism, a student of Jean Piaget, focuses on the art of learning, in other words, **learning to learn**, and emphasises **making things in learning**. Papert argued that knowledge is actively constructed by people who interact with their world. His discussion focused on how learners engage in conversation with artefacts (their own or those of others) and how these conversations enhance self-directed learning and facilitate the construction of new knowledge by each learner.

Below, I further discuss constructionism and design-making.

2.5.1 Constructionism for co-creation and complex challenges

Assume that everyone is different and that a prototype is a socially constructed artefact. If this is the case, design researchers, educators or workshop facilitators must understand how a person creates an early design concept or initial prototype that will enable collaborative prototyping (co-prototyping) at a later stage. In addition, it is essential to support the practice of collaborative design platform or cooperative inquiry (Heron, 1985) in the context of product design research and design implementation with and for the public. Due to the growing need to develop more appropriate and better perceived designs for the public, the participatory design or co-creation design approach is often adopted in the workshop design process in which design teams involve stakeholders with different backgrounds and motivations as designers.

Two major emerging needs have pushed professional product designers and design educators to adopt participatory or co-creation design more often (Laurel, 2003). First, traditional design fields (such as design for the manufacturing and business development industries) and non-design fields (such as design for social innovation, community development) require collective and collaborative innovation. Second, the participatory design approach and co-creation approach have been further promoted and developed due to the growing practice of user-centred design, public engagement and interaction and citizen ownership and stakeholder empowerment. As a result, designers need to know the theories and methods required to overcome these new challenges.

According to Mark Guzdial (2018), constructionism is

> more of an educational method which is based on the constructivist learning theory. Constructionism, invented by Seymour Papert who was a student of Jean Piaget … he believes that students will be more deeply involved in their learning if they are constructing something that others will see, critique, and perhaps use. Through that construction, students will face complex issues, and they will make the effort to problem-solve and learn because they are motivated by the construction.

Mabogunje et al. (2008) explained the differences between constructivism and constructionism, which are relevant to the design of this research. According to their description, **Jean Piaget** stipulated that children actively construct and rearrange knowledge based on their own experience in the world. **Seymour Papert** further drew on the constructivist theory by asserting that constructivist learning can be enhanced by engaging in the construction of external things. In addition, Papert developed his ideas and those of Piaget for adults. Mabogunje et al. (2008, p. 3) further pointed out that constructionism is **‘a way of making formal, abstract ideas and relationships more concrete, more visual, more tangible, more manipulative, and therefore more readily understandable’**.

2.5.2 Constructionism for product design training

Kim et al. (2015) discussed the constructionist learning perspective in environmental product design education. According to Papert’s definition, constructionism is a pedagogical approach that encourages learning through constructing, designing or making a product. Although constructionism was developed from constructivism, the two are not similar.

From a constructivist point of view, people construct their own version of reality by absorbing abstract and formal knowledge from the context of their learning, which occurs when people perceive their reality internally through collaborative construction.

In contrast, constructionism proposes that knowledge is not built in the minds of learners. Instead, personal learning is context specific and knowledge is shaped by interactions with external support. From a constructionist point of view, learning is a cyclical process of construction whereby learners externalise the initial state of knowledge by constructing an object that updates prior knowledge, then interprets and reconstructs new knowledge. In other words, learners learn effectively when they design or construct something tangible.

There are two aspects of learning in constructionism: scaffolding and autonomy. Scaffolding does not provide a final answer to learning. It is about structure and guidance, offering hints, establishing task structure and coaching. Scaffolding facilitates the learning of complex and difficult tasks by making them more accessible and manageable, enabling student-centred development. It aims to help students understand why they are doing a task and how to do it. Autonomy is a self-initiative situation in which students acquire motivated and responsible learning and act autonomously.

Chapter 3 Research methodology

In this project, I assumed that designers or workshop participants who excel in prototyping make more accurate and sophisticated evaluations at the final stage before delivery. Why do designers spend so much effort and time on exploring appropriate forms (compared with other processes in a design project)? In a way, this reflects the reality (essence of intention) that by shaping a new form with a sensible argument, designers seek to persuade or communicate with others with some kind of meaningful value. This could promote a way of living better and meeting the needs of customers and/or society. This notion was examined in this research.

To collect valid data, this study used a longitudinal perspective based on historical evidence from the literature review (macroscopic) and the subjects' individual perceptions of design, case reflections and perceptual design tasks (microscopic). To this end, a qualitative research approach with content analysis was adopted. Triangulation of the different methods helped verify the results. For more details, please see Chapter 3.1.3 for an overview of the research methodology.

3.1 Theoretical Framework of the Study

3.1.1 Perspective on learning – Constructionism

This study followed the underpinnings of **constructionism,** suggesting that a design workshop is a collaborative learning environment that helps participants to learn by creating their own design concept and further enriches their learning by externalising the concept through prototyping, such as sketching. They internalise learning through sharing, reflecting and developing their own concepts and the concepts of others during the workshop. This process is essential to participatory design, as people construct their own learning experience through collective creativity and acquire a sense of participation, ownership, self-actualisation and, most importantly, reach mutual agreement or understanding.

Thus, I framed this research from the perspective of learning experience, which guided the development of the interview questions, questionnaire and design task. The design task of the research aimed to measure the participants' creative design process (rather than the point at which they collaborated) and I assumed that their personal involvement in the early stage of the participatory design process was essential. Indeed, a better articulated conceptualisation of the participants in creative design should improve concept evaluation or high fidelity prototyping in the iterative process.

3.1.2 Perspective on design – User-centred design and interaction

In addition, the research was based on pragmatism. This was a useful and effective means of enriching the participants' understanding of product design activities.

User-centred design approach (from pleasurable experience to aesthetics)

Product designers seek to design products that can meet people's needs based on the hierarchy of consumer needs (functionality, usability and pleasurable experience) proposed by Jordan (1998, 2000, 2002). Jordan adapted the classification of four pleasures (physio-pleasure, socio-pleasure, psycho-pleasure and ideo-pleasure) developed by Lionel Tiger (1992). This framework of four types of pleasurable experience facilitates the work of designers by helping them to consider all of the potential kinds of pleasure derived from a product. This tool has received positive feedback from design researchers and design educators in the field of user-centred products. In addition, interaction designers generally find Jordan's framework very applicable and inspiring. It expands understanding of the levels of utility of a product and emerging concerns about user-product interaction, such as user perceptions, satisfaction and feedback.

Jordan (2002) examined the practical benefits of understanding 'pleasure' as follows.

> The *Oxford English Dictionary* defines it as 'the condition of consciousness or sensation induced by the enjoyment or anticipation of what is felt or viewed as good or desirable; enjoyment, delight, gratification. The opposite of pain'. In

the context of products, pleasure can be defined as ‘Pleasure with products: The emotional, hedonic and practical benefits associated with products’ (Jordan 1999).

Interaction design

In interaction design, people are diverse, complex, nuanced and engaged in subtle and skilful social and material interactions. Many studies have focused on users and the environment in response to the user-centred design approach and design for sustainability, respectively. Studies of user needs have provided designers with a rich understanding of physiological needs (e.g. ergonomic study), psychological needs (e.g. consumer preferences) and social and community needs (e.g. participatory design).

There is no doubt that these multidisciplinary studies (including various design approaches, tools and contextual understanding) have helped to promote better living and empowered designers to engage in more complex social, economic and environmental situations. However, this nascent complexity of design has posed a critical problem, as integrating multidimensional knowledge and contextual information requires a conglomerate of high-level reasoning methods to do the job ‘right’. There have been many discussions of new frameworks, models and tools to facilitate and optimise problem solving techniques and the product development process. It has been shown that designers encounter ill-defined problems for which abductive thinking is essential in the design process. However, little research has examined how designers reason in actual work, especially the processes of exploration and decision-making when transforming a relatively abstract verbal concept (written or in one’s mind) into a more concrete prototype through visual-spatial reasoning via mental modelling in the minds of designers, sketching or computer visualisation. Therefore, first, I investigated how visual-spatial reasoning affects prototype-ability. Visual-spatial reasoning is a type of inference directly dealing with the interactions between people, artefacts and the environment and the materialisation of concepts and values. This research work also explored the parameters and their contribution to constructing a prototyping experience individually. In addition, it was assumed that an articulated prototype formulated by an individual designer supported appropriate communication with the other participants in the collaborative design environment.

Therefore, the design task of this research examined the performance (experience) of individual designers on a continuous design exercise. More detailed research methods are developed in the next chapter.

3.1.3 Overview of the research methodology

The diagram below illustrates the methodology used in this research and the relationship between the main components of the research actions, including a literature review, data sources, research methods and questions, to establish the argument of the work and formulate a strategy to enhance the **prototype-ability of the participants in the workshop process**.

The main mechanism of knowledge building was the triangulation of the three data sources, as shown in the diagram. Alan Bryman (2008, p. 379) explained that **triangulation** is a study method that combines multiple observers, theoretical perspectives, data sources and methodologies. It focuses on study methods and data sources. It is a promising method as it can be carried out using an unobtrusive approach. Triangulation can take place in quantitative and qualitative research strategies and is used to cross-check the results. For instance, ethnographers can adapt their interviews to check the validity of their observations to ensure that they did not misunderstood what they saw.

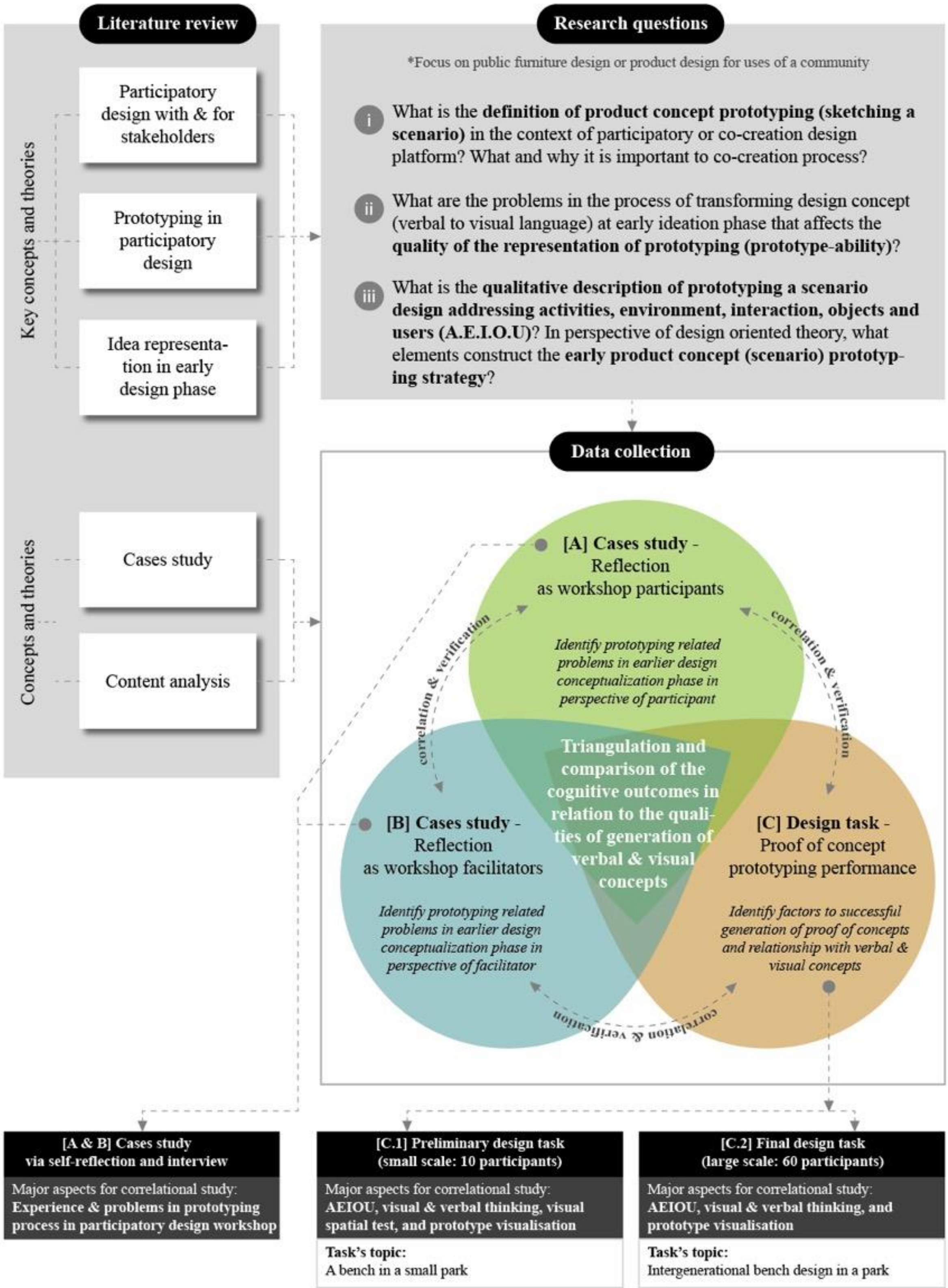


Figure 3.1 Overview of the components of the research actions.

3.2 Research methods

This study focused on the outcomes of the designers (participants with design and non-design backgrounds) during the **idea brainstorming** and **early concept visualisation** stages. In addition, a **triangulation** approach was adopted through the implementation of **case studies** and **content analysis** to understand the **cognitive processes of the designers** while prototyping their **initial product concept** from three data sources: i) **reflective analysis** as **facilitators of design workshops**; ii) **reflective analysis** as **participants in design workshops**; and iii) **cognitive skills** in design prototyping as participants in a design experiment.

The main methods are discussed in the following sessions.

3.2.1 Case study

3.2.1.1 Characteristics of the case study

As described by Alan Bryman (2008, p. 52), a basic case study involves a **detailed** and **intensive analysis of a single case**. Bryman cited Stake's (1995) definition of a case study as focusing on **complexity**, especially the nature of the case in question.

Bryman (2008, p. 53) further explained that in general, a case study is associated with a **location,** such as a community or an organisation, and is based on qualitative research, which includes the generation of an intensive and detailed examination through **participant observation** and **unstructured interviews**, for example.

The case study as a research method has been criticised because its results are not generalisable. However, first, Stake (1978) argued that the case study is useful for exploring explanatory laws and building an experiential understanding of humanistic meaning creation. Indeed, it helps the researcher delve into people's experience, and the case and the people involved are in epistemological harmony, which is a natural basis for generalisation. Natural experience, for instance, can help the reader understand social problems and social programmes. Second, the case study offers two types of knowledge: propositional knowledge and tacit knowledge. **Propositional knowledge** is composed of sharable statements (observations of objects and events). In contrast,

tacit knowledge is the experience of inexpressible associations related to new meanings, new ideas and new applications.

Stake (1978) further elaborated that the characteristics of the case study method are usually more suitable for expansionists than reductionists. In terms of theory building, which analyses the essence, the pervasive and determining ingredients and the making of laws, the case study builds theories through proliferation rather than narrowing down. Therefore, the case study can add new meanings to current experience and humanistic understanding.

3.2.1.2 One of the first case studies in participatory design

The case study is a prominent method of understanding how people create meanings. Thus, it can be used to explore how to enrich the participatory design approach in the design workshop setting that may relate to various design problems, such as architecture, product and other service design challenges.

To discuss the participatory approach to the **technology-driven product design process**, it is important to examine discourse in the United States since the introduction of computers to the workplace in the mid-1980s. Although a growing trend suggests that technology is embedded in artefacts and everyday life, the participatory design approach has become essential in the development process in **design for non-professional environments**.

What is technology?

It is important to define technology to anchor the discussion of product design with technology in the current context. ‘Technology is the means and methods through which we as a society produce the substance of our existence’ (Emspak, 1993).

Seeking to promote democracy and improve product quality by involving users, a group of IT professionals contributing to social responsibility organised the first **participatory design conference** in Seattle in 1990 (Schuler & Namioka, 1993). European, Scandinavian and American approaches were shared, in which the writers reported the various ways (with rich and diverse perspectives and experiences) to engage with problems and possibilities in an authentic yet cooperative process of technology design (such as the systems development process) rather than a general and unified model for a specific situation.

Schuler and Namioka (1993) emphasised some of the fundamental changes brought by participatory design to the traditional design approach. For instance, they rejected the assumption that technology (i.e. computerisation) should replace people. Instead, it should support users with better tools to fulfil their tasks by considering users as experts in their lives and designers as technical consultants. Significantly, they advocated that computers and computer-based applications should not be isolated in the systems development process in the context of the workplace. Thus, this approach is perceived as a process rather than a product.

This is a valuable resource to support product designers to formulate a collaborative design approach with and for stakeholders to deal with complex users and technological contexts.

A design workshop is a type of teaching or training platform that introduces specific knowledge through design thinking and helps participants solve design-related problems. Chapter 4 analyses 12 case studies of different design workshops, focusing on the early phase concept prototyping process.

3.2.2 Design tasks in design research

To understand the **mechanism of the concept generation process, from verbal concepts to early phase concept prototypes,** and identify the factors that affect the quality of prototyping, it is necessary to study the performance of designers in specific tasks. The discussion below reviews this approach, which can guide the formulation of methods for this research.

Comparing novice and experienced designers is one of the research approaches to understand the characteristics of the performance of designers (Ahmed et al., 2003).

Prototyping is an approach to the design process used by most creative professions and academia. In particular, a **prototype** plays a crucial role in the **iterative approach,** increasing the chances of **success of the deliverable** or **reducing mistakes or inappropriate design,** which may induce higher investments in resources and unsustainable solutions. In terms of enhancing **creativity and community participation** to address **complex problems,** such as **product design for public use**, a prototype allows different users or a group of stakeholders to experience and share feedback based on a physical object that provides more concrete information than a verbal description. This concrete information includes the properties and states of a product and its physical, symbolic and cultural relationships with other contexts, such as the interactions of users with the product, the situation, the environment and other people and/or objects.

Design task topic – Designing a bench for an intergenerational park

Product designers have been involved in **social innovation projects** since the last decade in Hong Kong. The researcher for this project was an active practitioner collaborating with non-governmental organisations (NGOs), the professional design society, public and private organisations and other individual community members. Prototyping as a platform to facilitate public engagement, ownership and initiate discussions and interventions to make **social value change** is the common action or practice used in collaborative work or participatory design projects to **address societal issues** and **test assumptions** in the community.

Therefore, the design task of this research focused on an emerging enquiry in Hong Kong in recent years: intergenerational harmony in a park. This public design challenge was a typical wicked problem, involving different stakeholders and policies.

Mapping personal abilities and reasoning preferences

As discussed earlier, the thinking preferences of designers can affect their performance in creative tasks. A self-evaluation of the five main intelligence profiles examined the possible correlation between visual and verbal thinking abilities and the quality of idea brainstorming and scenario sketching or prototyping.

3.2.2.1 Preliminary study

<u>Preliminary study – Design task (14 samples with different disciplines)</u>

Design performance in prototyping was the main problem space investigated. In this research, ‘prototype’ referred to an early phase concept (proof-of-concept) prototype in the early phase of the concept development process. In professional design practice, the early phase concept prototype can refer to different forms, such as (i) the visualisation of a concept or group of relevant concepts through sketching, scenario, storyboard and computer model, and (ii) the physicalisation of a concept or a group of relevant concepts through mock-up, 3D printing, quick scenario or environment simulation. This research focused only on sketching as a visualisation task performed by the workshop participants. The participants’ performance involved the process of completing or accomplishing a task in which the quantity and quality of actions were assessed. The preliminary study explored and evaluated whether the content of the design task was appropriate.

The research questions focused on the human factors (e.g. differences in design performance between design-trained participants and non-designers), the content of the actions (e.g. relevance to the innovation design challenge at the community level), the level of the actions (e.g. the difficulty of the actions, their duration) and the factors affecting productivity and creativity.

Regarding the choice of topic, it followed the scope of the case studies mentioned in this research. The cases analysed participatory design in the field of park design and product design for the elderly. Several relevant keywords were involved: park facilities, park service design, age-friendly product design, ageing in place, active ageing and intergenerational design. Some items, such as age-friendly products and park facilities, were massive projects involving too many factors and requiring more time and knowledge to deal with uncertainties. To limit the scope and challenges, a bench design with intergenerational harmony concerns was selected for the design task. It was assumed that a bench is a common product in public spaces and that most participants should have experience of the seating and environmental setting. Therefore, it should be easier for the participants to imagine and explore other opportunities.

A

Personal Data Sheet

Project: Design abilities in idea generation and prototyping process

Remark: The data you provided may be used for academic study and dissemination, and be treated anonymously. If you don't agree to release your data, you

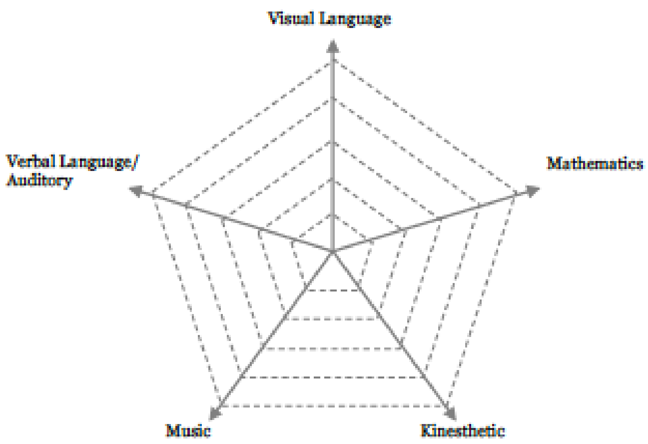
Section I- Self evaluation. Please give yourself a moment to reflect upon the followings:

1. Abilities preferences

(Use "•" to indicate the level as appropriate)

Descriptors:

- **Visual language** - higher rating if you are good at visual memory, comfortable with think and solve ideas visually.
- **Mathematics** - higher rating if you are comfortable & strong in mathematical thinking.
- **Kinesthetic** - higher rating if you are good at thinking through making physical model by hands.
- **Music** - higher rating if you are sensitive and good at musical thinking.
- **Verbal language** - higher rating if you are good at verbal memory, & comfortable with think and solve ideas verbally.



2. Personal information: (may put a "✓" in the box. ☐)

2.1 Age range:

☐ 15 to 20 ; ☐ 21 to 25 ; ☐ 26 to 30 ; ☐ 31 to 35 ; ☐ 36 to 40 ; ☐ 41 to 50 ; ☐ 51 to 60

2.2 Education level:

☐ HD or Asso Degree (discipline:____________________; years of study (if applicable): ________)
☐ BA/ BEng (discipline:____________________; years of study (if applicable): ________)
☐ Master or above (discipline:____________________; years of study (if applicable): ________)

3. Experience	
3.1 Had you participated any design workshop out of design class? Your roles?	☐ Yes; ☐ No Roles: ☐ participant; ☐ facilitator; ☐ coordinator; ☐ others____________
3.2 During meeting or seminar, how often you make notes with verbal language in majority of your time?	☐ below 10%; ☐ 10-25%; ☐ 26-50%; ☐ 51-75%; ☐ 76-90%; ☐ above 90%
3.3 Do you enjoy illustration (sketching or graphical representation)?	☐ Strongly disagree; ☐ Disagree; ☐ Average; ☐ Agree; ☐ Strongly agree
3.4 Do you enjoy handicrafts or making things?	☐ Strongly disagree; ☐ Disagree; ☐ Average; ☐ Agree; ☐ Strongly agree
3.5 In group work, your roles usually are? (please mark 1,2,3...to indicate the roles that usually shows your strength & contribution the most)	☐ Notes taking; ☐ Raising/ articulating concept in verb; ☐ Raising/ articulating concept by drawing; ☐ Verbal data analysis; ☐ Visual data analysis; ☐ Visualization of the concept; ☐ Model making; ☐ Report writing

Figure 3.2 Personal data sheet to collect the participants' preferences on the five main thinking abilities and other personal information.

Examining idea brainstorming and design concept prototyping through scenario sketching

To implement the task in a real setting, the scenario should not be complex and the task should be possible to complete during a typical workshop session, generally one to two hours. Thus, the topic was further limited to a bench design for intergenerational harmony in a small outdoor park. To facilitate a more complete and effective idea brainstorming session, the AEIOU framework was adopted.

AEIOU framework

The AEIOU framework is a relatively holistic and systematic method that supports observational (ethnographic) planning, data collection and idea classification for a potential design concept. Other frameworks could have ben used, such as POEMS. However, the AEIOU model is preferable for the development of service design.

While working for the Doblin Group in 1991, Rick Robinson (2015) and his group were the first to develop and adopt AEIOU, which they used to study over-the-counter interactions in McDonald’s restaurants. After clustering and categorising the data, they proposed the categorical AEIOU framework presented below.

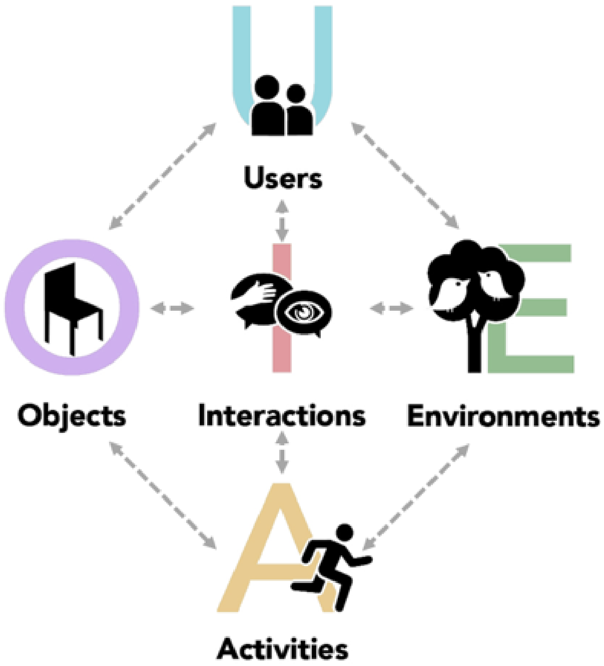


Figure 3.3 Modified AEIOU framework from Design-led Research Toolkit (http://dlrtoolkit.com/aeiou/). The five attributes, activities, environments, interactions, objects and users (stakeholders) are interconnected. I have arranged the 'users', 'interactions' and human 'activities' attributes at the top, middle and bottom of the diagram, respectively, to emphasise human-centred design.

AEIOU is a coding and mnemonic scheme with five attributes: activities, environments, interactions, objects and users. It is usually applied to two concept generation activities. First, it supports ethnographic or observational methods, such as note taking, photo taking and interviews, while the researcher codes the scattered concepts collected from the data pool or a brainstorming activity according to the five attributes. Second, it guides people to collect, brainstorm or explore concepts under the five attributes in the research field or a design activity.

According to Rick Robinson (2015), the framework is customisable and a new taxonomy can be applied. Both approaches facilitate the interpretation and analysis of the data, which are mapped visually with clear categories showing the relationships and interactions between all attributes or factors of a design problem or solution.

Mark Baskinger and Bruce Hanington (2011) developed the AEIOU design thinking worksheet and shared it in an online book called *Drawing Ideas* in 2011. It is worth noting that Robinson initially presented AEIOU as a customisable framework, while Baskinger and Hanington considered the five dimensions as a rigid system in their toolkit.

Definitions:

Activities: actions with specific goals and processes to achieve these actions. This attribute records the types of activities (e.g. dancing, tai chi, reading a newspaper).

Environments: contexts and characteristics of the space in which the activities take place (e.g. sun orientation, size, plants).

Interactions: sensory experiences and perceived concepts (affordance) in intra-personal, interpersonal, user-object and user-environment interactions. Proximity and spatial relationships with other factors also play an important role, such as how users operate an object or how they are supported by the environment (e.g. seating and communication are facilitated).

Objects: the categories and characteristics of the items discovered or created in the environment. This attribute also applies to the central and peripheral application of the objects during the activities (e.g. types and features of an object, materials, colour).

Users: People involved in the environment and activities. This attribute also addresses the values, behaviours, needs and relationships of people (e.g. user profile (e.g. students, domestic helpers, seniors (young-old, middle-old, old-old)) and other stakeholders (e.g. park management team, nearby primary school); user habits, values and physical and mental preferences).

The 'interactions' attribute includes personal and collective experiences caused by other factors. Therefore, 'interactions' cannot exist alone. The other factors are tangible and may carry symbolic meaning. For instance, some 'objects' may have an impression or connotation related to the elderly. Some ‘objects’ are more childish. In addition, the participants may ignore the idea generation for the ‘environment’ and ‘user’ type.

B

Task: Idea brainstorming (I)
活動: 概念開發 (I)

Theme: **Inter-generational harmony park** 跨代共融公園 | Instruction: Please refer to below AEIOU items and brainstorm ideas as many as possible that fulfils the theme. Please fill in the three columns in white with **text-only descriptions within 15 mins.**

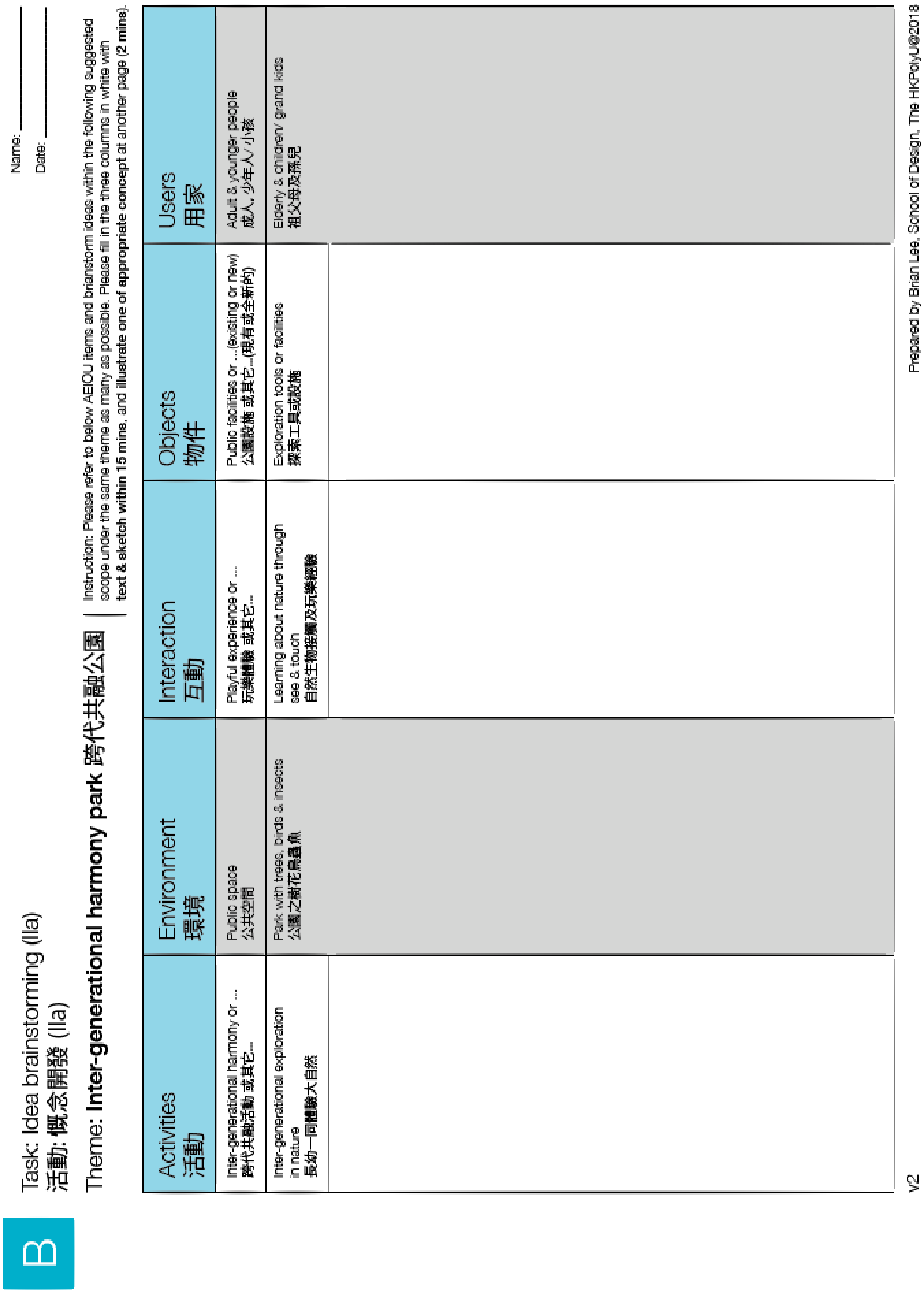
Name: ________
Date: ________

Activities 活動	Environment 環境	Interaction 互動	Objects 物件	Users 用家
Inter-generational harmony or … 跨代共融活動 或其它…	Public space 公共空間	Playful experience or … 玩樂體驗 或其它…	Public facilities or …(existing or new) 公園設施 或其它…(現有或全新的)	Adult & younger people 成人, 少年人/ 小孩

v2

Prepared by Brian Lee, School of Design, The HKPolyU@2018

Figure 3.4 Task sheet B (I) for idea brainstorming on the theme of intergenerational harmony park.



B

Task: Idea brainstorming (IIa)
活動: 概念開發 (IIa)

Name: ____________
Date: ____________

Theme: **Inter-generational harmony park** 跨代共融公園

Instruction: Please refer to below AEIOU items and brianstorm ideas within the following suggested scope under the same theme as many as possible. Please fill in the three columns in white with **text & sketch within 15 mins**, and **illustrate one of appropriate concept** at another page (**2 mins**).

Activities 活動	Environment 環境	Interaction 互動	Objects 物件	Users 用家
Inter-generational harmony or ... 跨代共融活動 或其它...	Public space 公共空間	Playful experience or ... 玩樂體驗 或其它...	Public facilities or ...(existing or new) 公園設施 或其它...(現有或全新的)	Adult & younger people 成人, 少年人/ 小孩
Inter-generational exploration in nature 長幼一同體驗大自然	Park with trees, birds & insects 公園之樹花鳥蟲魚	Learning about nature through see & touch 自然生物接觸及玩樂經驗	Exploration tools or facilities 探索工具或設施	Elderly & children/ grand kids 祖父母及孫兒

v2

Prepared by Brian Lee, School of Design, The HKPolyU@2018

Figure 3.5 Task sheet B (II) for idea brainstorming on the theme of intergenerational harmony park with examples. This was another attempt to help the participants quickly develop relevant concepts and to understand how they represented them through sketching.

In general, the product design prototyping process can encompass the entire design project, from **low fidelity** to **high fidelity** representation of design concepts generated during the non-linear iterative design process, until the delivery of the final prototype for production.

Designers generally produce a proof of concept (also called minimum viable product) at the beginning of the prototyping phase and generally represent the concepts in the form of sketches or simple mock-ups. This research only conducted a qualitative study on the **two-dimensional representation (sketch form)** of the **early phase concept (proof-of-concept) sketching-type prototype at the early ideation stage**. Prototypes in three-dimensional form were ignored.

As this research studied the conceptual transformation from a verbal into a visual concept, the **verbal concept** was explored through the idea brainstorming task based on the AEIOU framework. The **visual concept** was explored by asking the participants to sketch a scenario extracted or developed from AEIOU.

Why AEIOU? Why a scenario study?

During the idea brainstorming session of a design workshop, the facilitator can use different methods or tools to increase the quantity and quality of ideas generated by the workshop participants. There are **three main objectives of collaborative brainstorming in a design workshop**. First, the facilitator asks specific questions or focuses on a specific area (one or more items at the same time) to guide the participants to participate and share their thoughts and/or facilitate group discussion on a topic. Second, a group discussion can lay the foundation or a common agreement between the participants, which is an essential criterion for quality collaboration for future tasks. Third, the facilitator expects the participants to be open-minded (e.g. no prior judgement), creative (e.g. diverse ways of seeing things) and constructive. The outcomes may be irrational. However, to attain constructive results in a limited time, the facilitator may give restrictive instructions, such as brainstorming ideas within a framework. Some methods do not affect creativity, the most common being AEIOU and POEMS, which provide comprehensive frameworks for the participants to cover or address most components or situations in a product system or service design.

3.2.3 Content analysis

From a **quantitative perspective**, Alan Bryman (2008, p. 275) emphasised that **content analysis** is an approach to **text-based document analysis**, in which the researcher **quantifies** the content according to a **predetermined coding scheme** or **categories of concepts** in a systematic and replicable manner.

From a **qualitative perspective**, Alan Bryman (2008, p. 529, 531) explained that qualitative content analysis is a widespread approach to the qualitative analysis of documents. Researchers call it thematic analysis or ethnographic content analysis, which involves searching for or identifying the underlying themes in the collected materials (e.g. searching for themes in texts). He referred to Altheide's (1996) approach to differentiate it from quantitative content analysis. Using a qualitative approach, the researcher constantly revises the themes or categories as s/he extracts concepts from the materials. This is carried out as a recursive and reflexive movement between concept development and data sampling, data collection and data coding. It aims to analyse the data systematically and analytically in a non-rigid manner. In this process, the categories and variables guide the study, while other concepts can emerged in the process, involving a constant search and comparison of the relevance of situations, settings, styles, images, meanings and other nuances.

<u>Final design task (60 samples in different disciplines)</u>

Participants:

To ensure that a wide variety of reasoning methods were collected and studied, 60 designers with experience working on different types of products for more than 5 years were selected. This research sought to observe and collect empirical evidence of the designers' immediate reactions and feedback in visual-spatial reasoning to solve specific design problems.

Interview environment:

A comfortable and quiet environment was arranged to deliver the task and organise the interviews, whether the interviewees' work space or other spaces, such as a studio setting. A table with a lamp or light source, a chair and drawing tools (paper, pencils, coloured pencils) were provided. A video camera was used to capture the moment of design and record the feedback of the designers (image and audio).

Process (cognitive experience):

Each interview and all of the tasks lasted for two to three hours. Open-ended and structured interviews were used. There were two stages of data collection.

Stage I

A primary study was conducted and the results were used to inform the design of the tasks and tools of Stage II. I interviewed three designers and conducted an initial experiment on their ways of using visual-spatial reasoning in different contexts. It was difficult to identify the saturation point when the tasks and questions were perfectly refined. I refined the initial design of the tasks twice (three rounds of tests for the three designers). If there was no obvious problem, it was adopted in Stage II.

Stage II

In this project, at least 10 professional product designers were invited to participate in in-depth interviews with semi-open questions and several simple design tasks.

During the tasks, to obtain fresh and detailed information on the experience of the interviewees, the researcher (me) asked questions about the design process from time to time. After the tasks, a graphical tool was introduced to help the interviewees (designers) to reflect and express their experience, process and reasoning during the tasks.

Design tasks (Protocol analysis):

The study involved three design tasks. No tasks exceeded 30 minutes. A longer task would have involved too many design steps and the interviewees would not have been able to recall each one clearly and correctly.

Task I – Collecting evidence of visual-spatial reasoning

This design task was used to enable the interviewees to explore different types of visual-spatial reasoning methods by, for example, designing a coffee machine with different components and considering different workflows. The mechanical challenge encouraged the designers to adopt different types of reasoning to solve complex problems. It proved the existence of various types of visual-spatial reasoning. It also revealed how and why the visual-spatial reasoning methods were used.

Task II – Analysing the experience of designing a non-interactive product

The designers were asked to design a (non-interactive) product, such as a lamp. Their reasoning process was revealed through observations, questions and a graphical tool.

Task III – Analysing the experience of designing an interactive product

The designers were asked to design a product (with an interactive function), such as a lamp designed for a ‘smart’ home. Their reasoning process was revealed through observations, questions and a graphical tool.

3.3 Research hypothesis and research questions

In the following sections, I first introduce the research hypothesis and research questions, then the methods of analysing these questions.

3.3.1 Hypothesis

In the context of a social design project involving product creation, prototyping is one of the critical challenges that impedes the implementation of the innovative concept developed by a multidisciplinary team in a co-design project. For instance, based on my personal review and an interview with the project facilitators of two social innovation projects called Library Lab for a government library in Hong Kong in 2016 and The Park Lab for the Leisure and Cultural Services Department of Hong Kong in 2017, the prototyping stages were identified as the cause of the failure to meet the expectations of the organisers and the participants during the workshops. This problem puzzled me and many other facilitators I collaborated with.

Design is an embodied experience

Prototyping is an innate human ability practised in everyday life, including facilitating the recognition of patterns, evaluating the elements of the outside world and informing the reactions (psychological and physiological) to the material and natural world. It is the fundamental ability not only to support the movements or interactions of our body in the world, but also to facilitate the materialisation of the human world, for instance by creating tools and symbols. Prototyping is an embodiment of the cognition of the senses, such as vision, the movements and conditions of the body itself and the surrounding environment. It is a skill that can be trained and improved to a certain level. Well-trained designers or visual thinkers are more aware of the need to identify and better able to identify minor changes in visual information; they are better able to interpret visual concepts and verbal means of communication; and they have richer reasoning approaches and a better visual memory. In this thesis, the **parameters of prototyping** and how these **parameters were related** to the materialisation process, in particular the form-giving practice, in product design were studied.

As an experienced designer, I found that prototyping (an output based on visual-spatial reasoning) is often mysterious and inexplicable. Indeed, many designers do not want to discuss or answer questions about it. Designers prefer to learn something new and practical to solve immediate problems. In addition, they find it difficult to explain the nature of design to other stakeholders; for instance, why does it take them so long to come up with a simple and good design? Can design be explained? If it is related to the logic of materialisation, some patterns should be identified as a form of inference in design. Few studies have focused on visual-spatial reasoning in design. Instead, most studies have explored visual elements at an abstract level and emphasised the logic of the process. Few studies have been conducted at the practical level to analyse how designers manipulate a form and argue for minor changes in line, shape and proportions. Visual-spatial reasoning occurs during the external representation mode (e.g. sketching) and the internal conceptualisation mode (e.g. the mind's eye of the designer). Most of the time, it is not a sequential process, which is also difficult to follow. It is not possible to simply use a questionnaire or analyse the sketches, as they cannot give a complete or real picture of design reasoning. This explains why we found that some designers skip steps and that sketching is only part of the thinking or recording platform. Nigel Cross also combined sketching (physical evidence) and interviews to analyse the way of thinking of designers (using quotes), although his study did not address the construction of visual-spatial reasoning. To truly reflect the design process (focusing on visual-spatial reasoning in the form-giving process), I adopted a hermeneutic phenomenological approach to acquire qualitative data on the experience of individual product designers during the reasoning process in design. This well-established approach is effective for understanding the creation of meaning in a design phenomenon. If we want to know how designers manipulate materials and transform ideas to create new forms for appropriate solutions, we should ask a designer why s/he shapes the material in a particular structure. Designing is not a purely logical and sequential decision, it is a type of iterative, exploratory and meaning creation process of individual designers. Due to the abductive nature of design, it should not have a standard or universal answer. Designers may reflect and integrate their personal values or ways of seeing/perceiving into their design. This unique outcome can be directly affected by the abilities, values or beliefs of individual designers.

The **key hypothesis** of this research was that there are obstacles to progress when building a prototype collaboratively or even individually during the participatory design process. The research questions mainly focused on the beginning of the idea development stage: the proof-of-concept prototyping process. This was considered an important milestone in the design workshop, as the development of a well-articulated prototype as early as possible could be a stepping stone to user evaluation or engagement to collect high quality design feedback and enable the iterative process. This investigation focused on the transformation of the product design concept (the intergenerational park bench design) from textual representation to visual representation in the participatory design workshop.

3.3.2 Research arguments and questions

3.3.2.1 Form-giving strategy to facilitate design

I assumed that product designers (non-engineering-driven) perceive prototyping (the meaning production approach) as a key to or lens for making sense of a design, involving the use of visual-spatial reasoning to develop a possible solution. The experience of searching for a way out of a maze is a useful analogy for a design activity in which product designers find different paths and anticipate possible exits through trial and error by making assumptions and through exploration (abductive thinking). In addition, designers usually do not know the exit at the beginning of the game. Indeed, a maze usually has different exits (this is what designers learn during design thinking training. Moreover, an exit can be connected to one of the entrances of other mazes or to a bigger maze (a more challenging problem). Alternatively, the designers eventually realise that there is no exit under the existing game rules. They may try to create a new rule (e.g. reframing or reinventing a new model) to move forward. However, this does not mean that they can reach the predefined end goal. In fact, they may identify a new opportunity that they would never have thought of at the beginning of the game!

3.3.2.2 Neither subjective nor objective

Many people describe the work process in engineering as objective and quantifiable, whereas design is considered intuitive, subjective and a type of tacit experience that cannot be explicitly described verbally. In this research, I suggested that design can be evaluated empirically. In other words, design can be a subject of analysis. There are many elements of knowledge related to design. I focused on visual form-giving and the perceptions of form language in the practice of product design, the most relevant domain knowledge and skills that product designers find fascinating and are proud of.

3.3.2.3 Non-interactive product design experience vs. interactive product design experience

It would be useful to know the similarities and differences in the way designers adopt prototyping in different contexts and requirements, namely comparing the inference process and methods for designing non-interactive products and interactive products. Indeed, the results may inform curriculum design in education and management planning in commercial projects.

3.3.2.4 Questions about the correlation between designer capabilities and prototyping performance

Non-designers may encounter difficulties or may be unfamiliar with the transformation of abstract concepts into concrete experiences, which is an obstacle to co-creation. The main questions asked in this research were the following. What are the obstacles to building a prototype collaboratively during the co-creation process? Why and what are these factors? In which situation? In addition, follow-up questions informed the understanding of **prototype-ability**. They were as follows.

1) How does the shift between ‘abstract’ and ‘concrete’ design concepts affect prototyping collaboratively?
2) How many types of ‘abstract-concrete’ shifts exist?
3) How is ‘material processing’ related to prototyping effectiveness?

Visual-spatial thinking generally yields positive results in the collaborative prototyping process with different actors working together (design and non-design disciplines). The following questions about the correlation between thinking preferences and prototyping performance were examined:

1) Are participants confident or familiar with **visual thinking** also better in prototyping (sketching the scenario)?
2) Are participants confident or familiar with **verbal thinking** also better in writing verbal concepts concretely?

In this research, '**imageability**' and '**situatedness**' were used to measure the cognitive success of product designers to deal with the design process in the early conceptual prototyping stage from the perspective of instructional design theory (or constructivism).

The results helped develop a **framework** to enhance and assess the **effective facilitation of the product concept prototyping process** for individual projects and co-creation projects involving different stakeholders with and without art and design training.

The questions were integrated into the three consecutive stages.

- 1) **Case studies** of different types of design workshops were collected and compared. This stage aimed to identify the main problems of design workshops in the concept prototyping process.
- 2) Workshop I (10 participants from design disciplines).
- 3) Workshop II (60 participants from different disciplines).

Chapter 4 Case studies: Design problems in the transition from ideas to early phase concept prototypes, based on a review of different types of design workshop

Participatory design or co-creation workshops have become a common approach to social innovation in Hong Kong in the last decade. This is not new to academic discussions from a methodological perspective. The **transition from concepts to early phase prototypes** has rarely been discussed and its contribution to the successful delivery of a final prototype and/or a holistic product-service system has often been ignored. This chapter presents the aggregated results of my **critical reflections on my first-hand experience as a workshop planner, facilitator and participant** and **the opinions of others** on the prototyping process (at different stages), while coaching workshop participants to move forward (the transition) from design concepts to early phase prototyping activities. The participants' profile (age, gender and education) and the research contexts varied. The constraints are also discussed.

One of the main goals of this part of the research was to identify a **general picture of 'prototyping' problems** in design projects involving social innovation and co-creation. The methods included **(i) a review of workshop processes, (ii) interviews with participants and (iii) content analysis of the selected outcomes** (e.g. development of the concepts of the participants using specific idea generation or mapping tools) of the workshops.

I designed, organised and supported various participatory design workshops as a project leader and facilitator. Selecting different workshop training experiences was designed to identify **common problems** in the **prototyping process** involving participants from **diverse backgrounds**. In the following case studies (Table 4.1), 12 design workshops are described in detail and the early design phase and issues related to the design concept prototyping process and tools are further elaborated and analysed. To date, there has been **no in-depth study of the transition between concept brainstorming** (e.g. idea brainstorming in verbal language) **and early phase prototyping** (e.g. a mock-up or semi-functional prototype). However, I suggested that it was important to understand the mechanism of the process in which know-how or techniques can guide workshop facilitators and designers to effectively transform verbal/abstract concepts into visual/concrete concepts.

Table 4.1 Distribution of the 12 design workshop cases in terms of number of participants, duration and main goals (product design, service design, management system development and/or business model development).

Case	Workshop title	Number of Participants	Project duration	P	S	MS	BM	Main characteristics of the workshop
I	Co-creation programme with and for Silver Age 2015	** (40 participants)	**** (3 months)	*	*	*	*	Large scale and lengthy collaborative design process with different stakeholders; Information about planning a design workshop using the prototyping process
II	My Quality Home Living – The Elderly Creative Workshop	*** (80 participants)	* (half a day)	*				Adopting prototyping as the research approach to facilitate user feedback on design concept and user experience of 2D objects with 3D information
III	Preferred Elderly Home Design Exercise (3D tool)	* (10 participants)	* (half a day)	*				Adopting prototyping as the research approach to facilitate user

								feedback on the design concept and user experience of 3D objects
IV	Jockey Club Retreat Workshop	** (40 participants)	* (half a day)	*				Comparative study of the performance of the elderly with younger and educated people
V	KODW 2017 Elderly Design Workshop by RCA	** (40 participants)	** (2 days)	*	*			Information based on the user journey/scenario prototyping approach
VI	The Park Lab 2017	** (28 participants)	***** (6 months)		*	*		Large scale project with a large group of stakeholders without a design background. Civil servants also participated as designers with residents and members of the community. Text-driven exploratory workshop
VII	PolyU x HHCD Healthy Ageing in Hong Kong: Hong Kong Care Homes	** (20 participants)	**** (3 months)	*	*	*		Review of the project with academics, postgraduate and undergraduate students, using visual tools
VIII	Intergenerational Game Design	**	*** (5 days)	*	*			Co-creation with the elderly

	Workshop with and for the Elderly (HKCS)	(20 participants)						(stakeholders) in the early design and final product evaluation phases
IX	WeDesign Programme by JCDISI	*** (40 participants)	**** (3 months)	*	*	*		Application of quick and final prototypes with minimal user participation
X	Workshop for Community Service Platform Planning (Yi Pei Square)	** (5 participants)	* (half a day)		*			A case showing the common practice of social workers brainstorming new service design
XI	Elderly Service Design Workshop for Integrated Services Team	* (2 participants)	* (half a day)		*			Review of a small-scale workshop to facilitate the analysis of current services and explore future services
XII	Elderly Service Design Workshop for Home Services Team	** (20 participants)	* (1 to 2 hours)		*			Review of a small-scale workshop to facilitate the analysis of current services and explore future services

Index of workshop goals

P = Product design

S = Service design

MS = Management system Development

BM = Business model Development

4.1 Case I: Co-creation Programme 2015

CASE I
Large scale and long collaborative design process with different stakeholders

The first case was a **co-creation programme with and for Silver Age 2015** organised by the Jockey Club Design Institute for Social Innovation and led by me as the workshop planner and facilitator.

The programme was a co-creation platform aimed at establishing an alliance with key collaborators to explore innovative concepts through researching, designing and promoting ‘smart ageing’ products that met the needs of five groups of stakeholders: manufacturers, service providers, marketing/sales agents, users and product design professionals. The framework for the workshop was established to explore and understand the direction of the design platform for the elderly in Hong Kong (Figures 4.1.1 and 4.1.2). The workshop helped the participants address and explore a variety of emerging themes and methods, including **‘Active Ageing’**, **‘Ageing in Place’**, **‘Co-design’** and **‘Human-centred Approach’**, which became the framework for the product development process. Each team was led by a practising product designer and had a pre-assigned exploration topic. The topics were **‘mobility assistance’, ‘visual and auditory assistance’, ‘dementia or memory loss support’, ‘wearable health monitoring’** and **‘assistive furniture’** design.

Five teams successfully generated five tangible design solutions: drawings, specifications and prototypes for further evaluation of the feasibility of production and commercialisation. Cutting through the workshop process, the prototyping session was one of the areas worth discussing.

Figure 4.1.1 The Co-creation Design Workshop conducted in October 2015 was built on the experiences of the previous two years and an in-depth pilot study conducted in summer 2015.

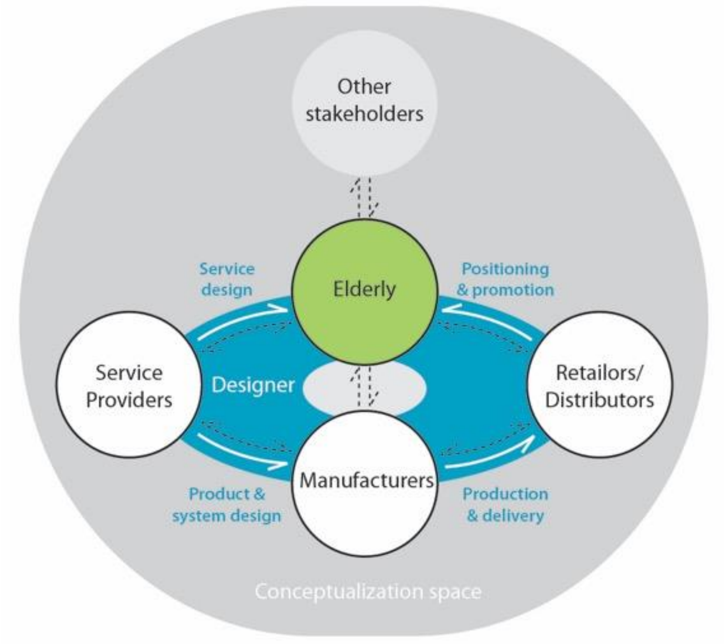


Figure 4.1.2 Framework of the co-creation platform of the workshop, to explore and understand the direction of the design platform for the elderly in Hong Kong.

Figure 4.1.3 General sequence of workshop processes, including a two-month pilot study and a three-day Co-creation Design Workshop in October 2015. Steps 4.1 to 4.5 describe the process of the intensive three-day design workshop involving all stakeholders, including the elderly.

4.1.1 Identification of issues and problems related to early phase prototyping

Although this programme was conducted for three months, the collaborative design phase lasted only three days. The remaining of the workshop consisted of user research and empathy mapping. The idea generation process took place according to the standard design workshop routine, including revisiting the situations identified during site visits, interviews and the profile study of the elderly living in public housing.

The workshop intended to **develop prototypes by identifying the unique and personal experiences of older people** related to active ageing and ageing in place. Therefore, a three-zone model was introduced to encourage the participants to explore the **user's journey** at home, in the community and while travelling. The participants also conducted home visits to several older people with different levels of physical problems, such as low mobility or low vision.

Figure 4.1.4 Co-creation session – Concept identification stage through mapping problems and opportunities on the three-zone map. The team leader (designer) discussed with the stakeholders to reframe the problems.

The participants easily mapped what they had experienced or collected during the research phase on the three-zone map (Figure 4.1.4). The idea development session went well and many ideas were collected. The designers and design students were assigned to each team with other participants from different disciplines. All team members shared their selected concepts at the end of the first day. The problems appeared after idea integration and concept consolidation. As expected, some team members struggled to make a final decision. Only the 'mobility assistance' and 'assistive furniture' teams used the quick mock-up approach to physicalise their **early phase concept prototype for decision-making and evaluation**.

Summary of identified problems:

- **Having good coverage of different stakeholders was not equivalent to representing the real interests of users:** The workshop involved different types of stakeholders related to the products for the elderly, including user groups, developers, manufacturers and wholesalers. However, most of the seniors were relatively young and active. They **could not represent real users** with chronic diseases or other physical and cognitive problems, as some project topics focused on the problems of older people with disabilities. In this case, home visits were conducted and older people were interviewed. In participatory design, users should be involved in the entire design process, from conceptual development to the confirmation of the final design. However, in this case, the real users were not involved in the concept development process. Therefore, the questions or assumptions related to prototype development might not have met actual needs or might have required critical review. To solve this problem, the real users should be invited to test the initial prototypes as soon as possible.

- **The workshop required professional knowledge:** The team identified different types of wicked problems, such as uncertain relationships between the **product's structure, functionality, usability, human and cultural factors (ergonomic, culture, aesthetics, behaviour and value) and cost**. In addition, most of these factors involved professional knowledge. Although experts were invited to give talks and share their knowledge, it was difficult for most participants to manage complex information, especially older participants. The visualisation tasks (such as product concept or scenario prototyping) were performed by the designers and engineers.
- **Designers dominated the visualisation process:** I discussed the process with the team leaders and found that they deployed various strategies to coordinate the participation of different stakeholders. For instance, one of the team leaders prepared a well-defined product rendering based on their assumptions after their preliminary research and adopted it during the three-day collaborative design platform. From my observation, the other members of the team (non-design background) did not make significant changes to the form and key features of the design proposal. The **early introduction of refined visualisation or prototype rendering** definitely affected participation and further development. This did not mean that the design was not appropriate, but that the designers dominated the design and the ownership of the other participants was weaker. A physical prototype should have been produced quickly to conduct real user tests.
- **Prototyping was a professional skill:** To my surprise, few of the non-design trained participants were able to build a model by manipulating basic model materials, such as pink foam, foam board and wooden sticks. Clearly, either the skills and tools were not user-friendly or other aspects prevented the transformation

from verbal concepts to tangible experiences. **Material knowledge and processing methods** were the two main obstacles to learning. Thus, in this case, the organiser mobilised the professional designers and design students to take care of the majority of the prototyping tasks. As with the previous visualisation problem, the drawback was that the designers **dominated the creative outcomes**.

- **Limited time**: It was obvious that the **concept generation session**, including **rapid prototyping**, was too short. The participants needed more time to study or review the collected data, which could have led to more in-depth understanding and insights. This is a limitation of typical design workshops, in which most participants are volunteers and have no obligation to participate as they are not the immediate beneficiaries.

Figure 4.1.5 Designers played a dominant role in the latter part of the idea brainstorming stage.

Figure 4.1.6 Designers and manufacturers discussed prototype design, including the form, technicality and feasibility. Other stakeholders were not involved.

4.1.2 Project reflection

According to our plan, we expected the designers to act as **representatives** of different stakeholders and to immerse themselves in the design process with other participants instead of a stand-alone designer (similar to professional practice). Unfortunately, most of the visualisation and prototyping tasks were carried out by the designers. According to the co-creation framework, the key stakeholders included the following:

1. Conceptualisation space: School of Design, HKPolyU; Jockey Club Design Institute for Social Innovation (J.C.DISI), HKPolyU
2. Elders (eleven participants)
3. Service providers: St. James Settlement; Yan Chai Hospital Social Services Department; Senior Citizen Home Safety Association
4. Retailers or distributors of elderly products: Culture Homes; Ho Ho Life
5. Manufacturers: Suga International Holdings Limited; Medisen Limited; Lamex Trading Co. Ltd
6. Designers: Innosphere; Bon Bone Design; Inno Box Design; Teaspoon; db design workshop ltd.

7. Other organisations: Elderly care-takers from other NGOs; Industrial Designers Society of Hong Kong; Institute of Active Ageing (IAA), HKPolyU; Eldpathy; Federation Hong Kong Industries

In conclusion, the **problems** in this case covered several concepts that required special attention to ensure **effective prototyping**.

i) **Lack of real representatives** (or real users).

ii) **Knowledge in different contexts** was needed.

iii) **Designer dominated.**

iv) **Different levels of professional knowledge** affecting the level of participation of different non-professionals.

v) **Concept generation and quick prototyping process were short**.

In addition, the diversity of the stakeholders (as indicated in the list of stakeholders above) and their education backgrounds or experiences, along with the workshop plan and tools, affected the effectiveness of the facilitation and outcomes of the workshop. Determining the **objective of a design workshop** is essential. If the purpose of the design workshop focuses on education to learn and promote the design process, the participation rate and the appropriateness of the implementation of the prototyping approach are more relaxed and open. If the organiser wishes to promote bottom-up participation and collect the real needs of users through co-creation, the recruitment and workshop processes need further adjustment.

The initial recommendation to improve concept development through prototyping (such as mock-up making) is to prepare appropriate model tools. It may be a modular system in which most non-professional participants can build a meaningful structure for evaluation. Foam and cardboard may not work for some people, such as the elderly. LEGO or similar block design systems may be a better option for non-designers. Transforming verbal or written concepts into visual or tangible structures appears to be a challenge and is essential for advancing the progress of a participatory design workshop with different non-design-trained stakeholders.

4.2 Case II: My Quality Home Living – The Elderly Creative Workshop

CASE II
Prototyping as a research method for a large group of participants

The My Quality Home Living – The Elderly Creative Workshop was a subsidiary activity of the Jockey Club Age-friendly City Project sponsored by The Hong Kong Jockey Club Charities Trust (The Club) and coordinated by the Institute of Active Ageing, The Hong Kong Polytechnic University. The Club is one of the top 10 charities in the world and supports the project to foster an age-friendly city and raise awareness of active ageing in Hong Kong. Local seniors generally live in small, self-contained flats for one to two people (between 14 and 17 m^2) in high-rise public housing or in small partitioned rooms and suffer from limited space and inappropriate interior and furniture design. The current design cannot meet the needs of the elderly and the needs caused by the process of continuous ageing (e.g. ergonomic changes of the body) and chronic diseases. I was invited to lead a group of researchers to engage local seniors and examine their preferences for quality of life at home and the use of interior space and furniture through the creation process. A play-based tool was developed for the investigation.

I argued that current living environments (including spatial and furniture design) could no longer perform as they were expected (there was no design agenda for older people living in high-rise apartments decades ago) and could not satisfy the heterogeneity of older people living independently. The project undertook a participatory design study to i) allow different seniors to share their home preferences; ii) collect their views during the design workshop; iii) formulate design guidelines based on feedback/cases; and iv) raise public awareness of the real needs of the elderly and inform future design directions. The Age Friendly Interior Design Workshop was conducted with **80 seniors** and provided them with a visual tool to **prototype the layout and features of their preferred home furniture**.

The creative prototyping toolkit developed to support the elderly workshop is presented below. The tool consisted of a set of two-dimensional graphical representations of a home environment and home products. The principle of development of this prototype tool was based on the assumption that few older people have adequate academic education. Some of them may have poor verbal expression, including writing and oral articulation. Thus, the tool was designed to help them share their design concept (such as spatial relationship, home activities and user experience) through a creative task rather than writing or through interviews only. Two typical floor plans (14 m_2 and 23 m_2) were provided. It was assumed that the 14 m_2 plan had limited space use possibilities and that the informants would be forced to focus on their basic needs or most important needs. After finishing the smaller plan, the elderly focused on the 23 m_2 plan, which was supposed to allow a reflection on the previous exercise with the 14 m_2 plan. They were expected to explore other uses or create additional features that the 14 m_2 plan did not allow. The participants were invited to imagine their preferred home living design based on these two plans.

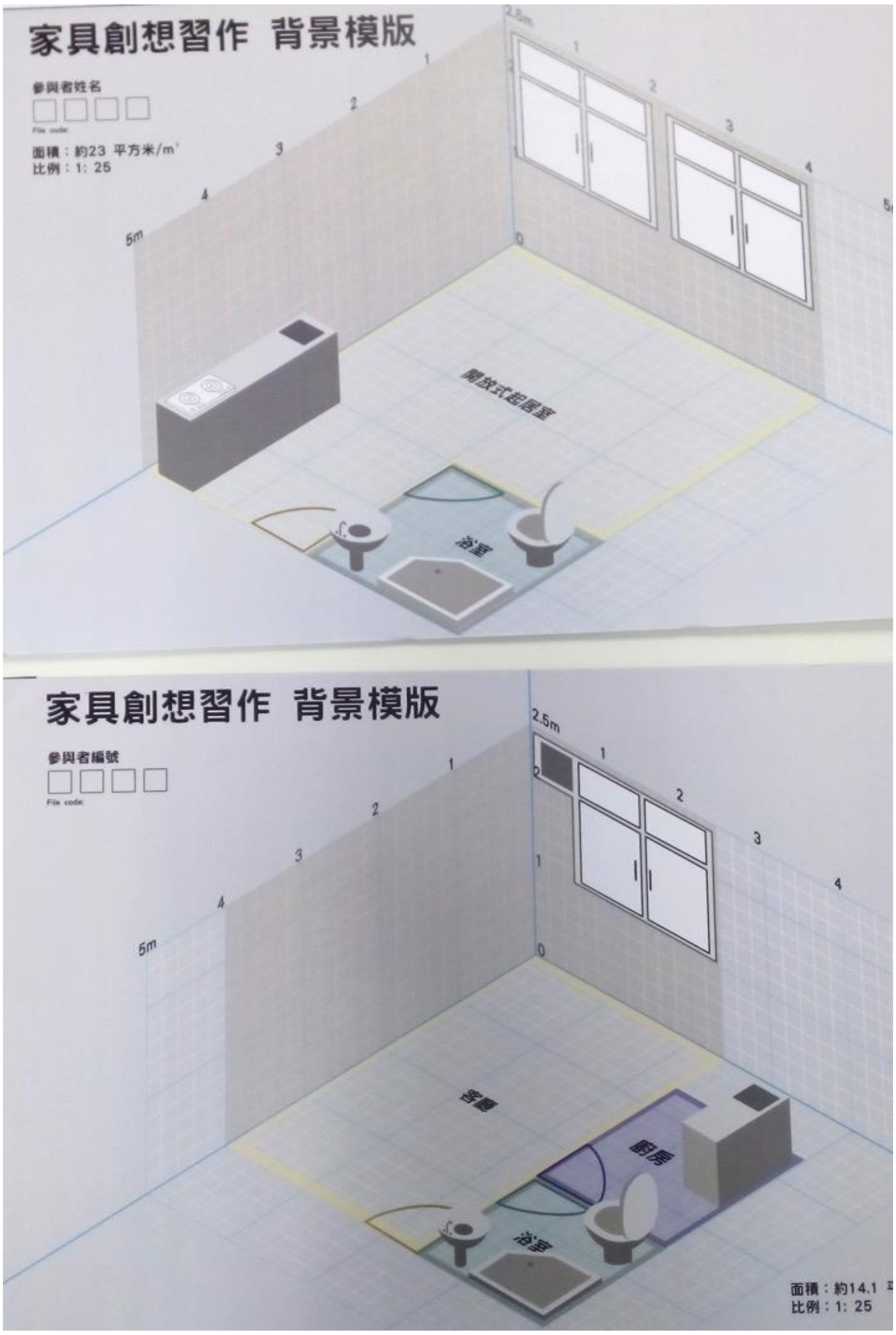


Figure 4.2.1 A set of two floor plan templates, illustrating two common floor areas (14 m_2 and 23 m_2) for one to two seniors living in Hong Kong. The 14 m_2 plan was a standard type of public housing for one to two persons. The 23 m_2 plan had an open plan kitchen provided on the private market.

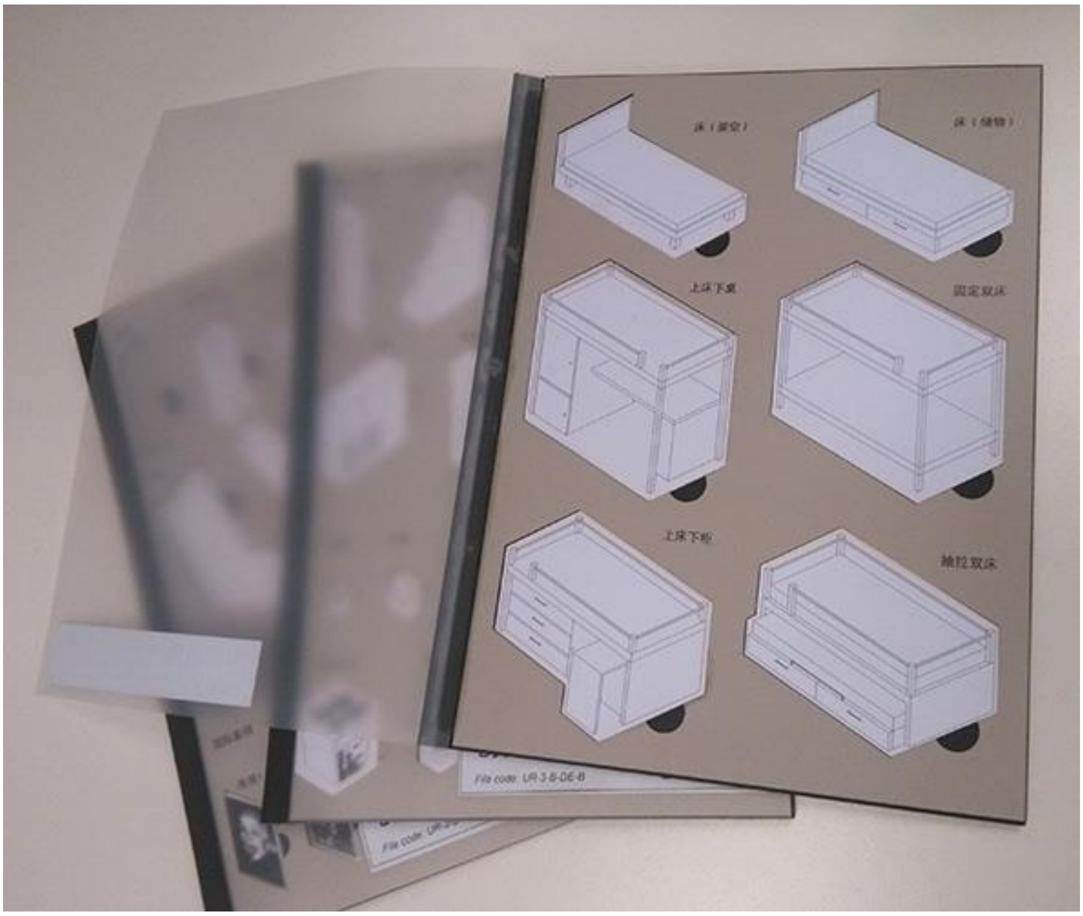


Figure 4.2.2 Examples of furniture images in isometric view, produced to explore the preferred living environment setting of the elderly.

4.2.1 Identification of issues and problems related to early phase prototyping

The furniture puzzles and floor plan templates as a method to enable user engagement and imagination was not new to design researchers. However, this project challenged me as it was the first time that I devised a visual tool to help a large group of older participants (80 seniors) from diverse backgrounds to carry out the same creative tasks. The goals of the workshop were to collect the participants' perceptions on **(i)** their **user experience** and **(ii)** their **expectations of two apartment designs** (14 m^2 and 23 m^2). It was assumed that some precision of the tools was essential to stimulate **appropriate memory and new associations**. By adopting the in-scale and isometric representation approach, the floor plan, furniture and other home products were produced to support the workshop.

A pilot trial was conducted with six active seniors, with some participants having higher education. During the creation process, it surprised me that more than half of the participants had difficulty manipulating or orientating the isometric furniture items. In the sample shown below, created by one of the participants (young-old), some of the furniture items did not match **the corresponding spatial configuration**. For instance, the refrigerator (on the left-hand corner of the floor plan) and the three-drawer cabinet (on the right-hand corner of the floor plan) are not aligned with the isometric guidelines. Another common mistake was the orientation of the furniture (the XYZ axis issue) corresponding to the floor plan. For instance, the large cabinet in the middle of the plan, near the toilet, lies on the floor instead of standing at 90 degrees. The washing machine, the shoe cabinet, the chair and the foldable table are also **disorientated**.

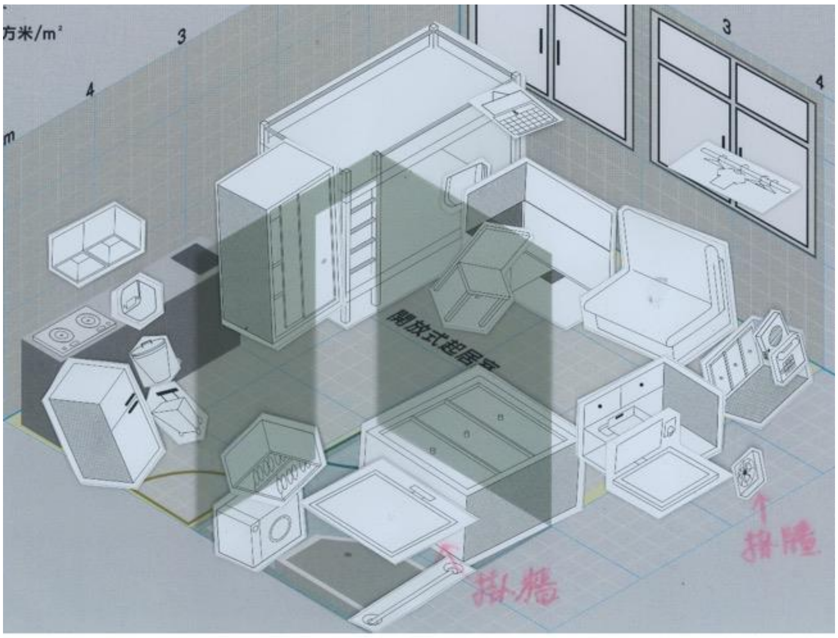
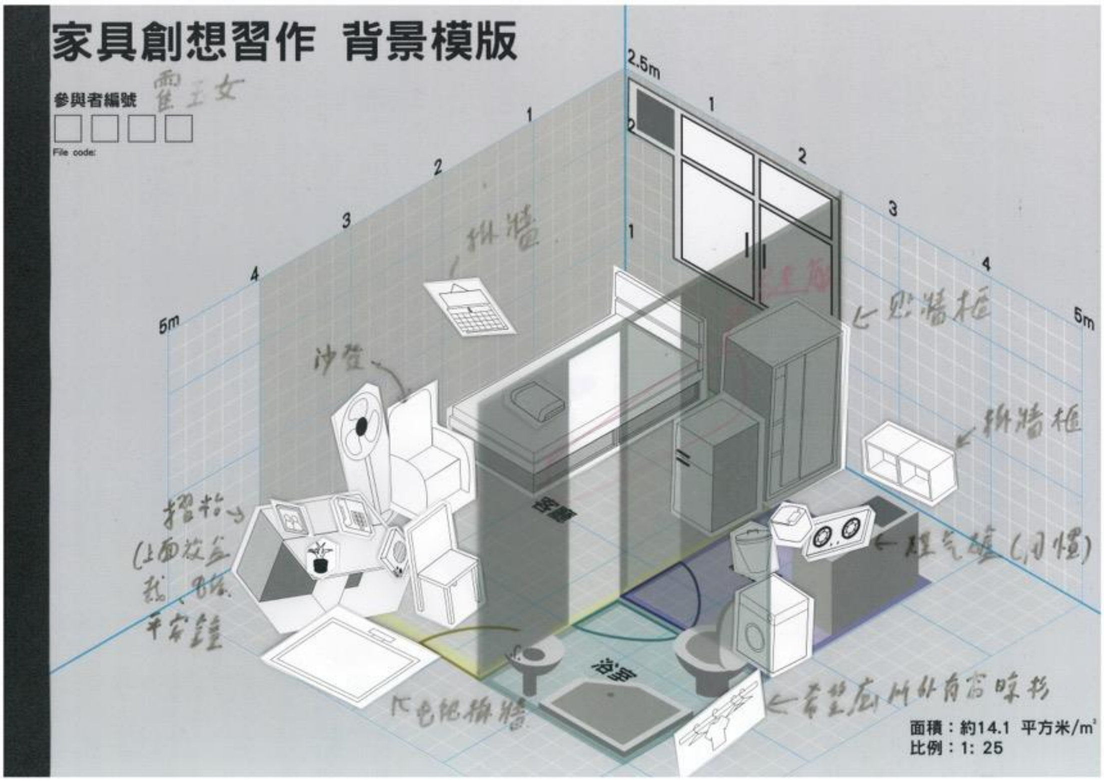
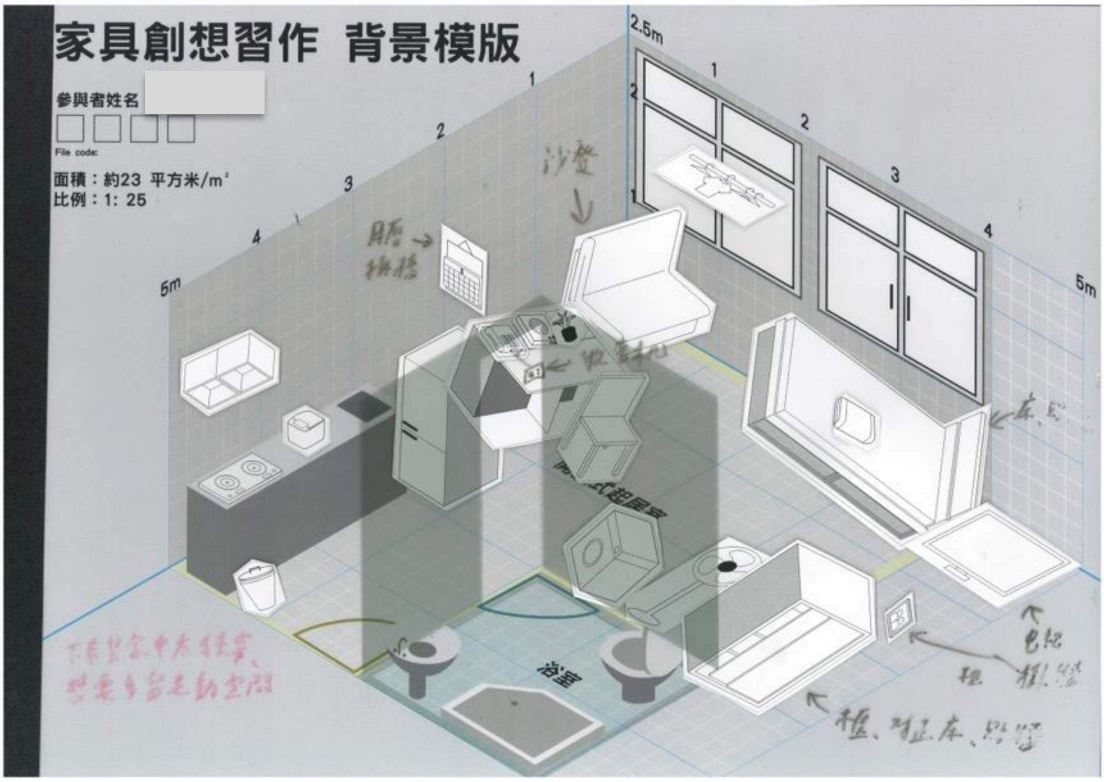


Figure 4.2.3 One of the sample tests carried out in the pilot study. The results indicated that it was difficult for some female seniors to align the isometric view with the furniture items and spatial design (floor plan and walls).

This phenomenon also occurred in the real workshop during which many elderly participants made mistakes with the orientation of the furniture items, according to the spatial indications suggested by the isometric floor plans with walls and grids.

The two creative works below (14 m^2 and 23 m^2 floor plans) were created by a female participant over 73 years old. She planned her preferred home design based on the two templates with different sizes and slightly different spatial features, spending about 30 minutes on each plan. When interacting with the creative tools, she carefully placed the furniture and home products according to her preferences. Like the other participants, she made mistakes. She could visualise the outcomes (choice and position of the objects) and make changes easily. She could also write some remarks if there was no proper choice or feature offered by the furniture or home product items. For instance, she emphasised the need to keep a fairly wide walkway next to the bed (as shown in the 14 m^2 plan) and deliberately created a more spacious area in the middle of the apartment (as shown in the 23 m^2 plan).





Figures 4.2.4 and 4.2.5 The two images above are the creative outcomes of the 14 m^2 (first layout) and 23 m^2 (second layout) floor plans designed by one of the participants over 70 years old.

Summary of identified problems:

- **Misalignment and misorientation:** The participants had difficulty manipulating the furniture or product items accurately.
- **Visual information facilitated trial and error:** This was important for concept exploration and modification.
- **Visual representation helped to articulate the user experience (intangible experience):** Compared with a normal questionnaire with verbal clues, more accurate user perceptions of their needs were collected through graphical or visual representations, in particular the concepts related to the spatial relationship between users and objects, the goal being to create a user experience.
- **The participants did not have direct experience of the research context:** The elderly did not have the experience of living in a 14 m^2 and/or 23 m^2 space. Many of the participants lived in apartments larger than 14 m^2. The lack of real experience made it difficult to formulate appropriate comments.

4.2.2 Project reflection

In conclusion, the results indicated that the tools successfully helped the users associate and carry out analytical activities on spatial quality. This was one of the factors contributing to the concept of quality of life of the informants, a rather **abstract and qualitative concept**. This information helped the researcher deepen his investigate and ask follow-up questions to the participants/informants. In general, this spatial and product design prototyping method is effective as an analytical tool for engaging and collecting people's perceptions in response to a specific type of environmental design and interactions with users, objects and related activities involving both a **concrete user experience** and an **abstract concept**.

4.3 Case III: Preferred Elderly Home Design Prototyping Approach (3D)

CASE III
Prototyping as a research method

This case study had the same objective as Case II, along with similar prototyping. I was the principal investigator of the project, which was supported by a departmental general research fund from The Hong Kong Polytechnic University. It investigated the real needs of the elderly at home using the prototyping method to collect qualitative data. The main difference was that the method was individual and used in the household environment. In addition, it used three-dimensional models instead of the two-dimensional items used in Case II. Furthermore, a new process was incorporated. First, the participants were asked to build their current home environment using the floor plan provided with three-dimensional walls and furniture. Second, they were invited to modify their current home environment based on their preferences for future use, such as the next 5 to 10 years. One of the goals was to encourage the participants to anticipate and explore possible changes in the near future. This method allowed the participants to gain **first-hand experience** while observing their current situation (more concrete and visual) and provided a sequential conceptual development, from **retrospective prototyping** to **prospective prototyping**. Ten cases were carried out in the pilot study to evaluate the prototyping method.

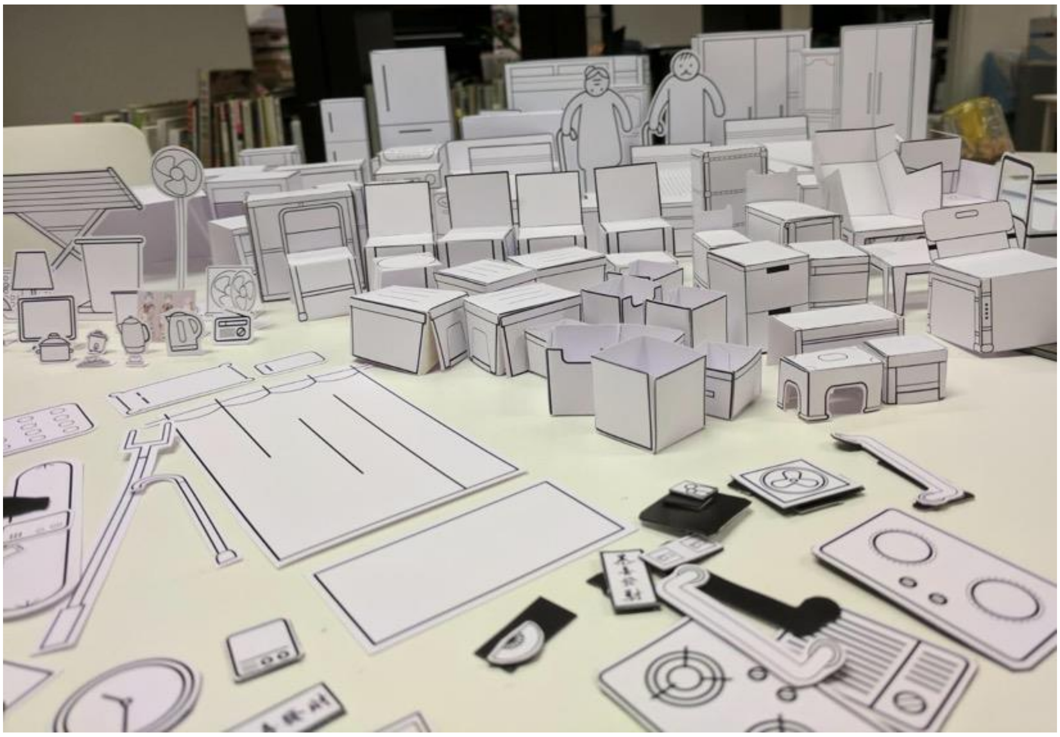


Figure 4.3.1 Scale (1:15) models produced for the creative exercise. The furniture models were made using three-dimensional paper cards. The smaller products and irregular items were made in two-dimensional format.

4.3.1 Identification of issues and problems related to early phase prototyping

As mentioned earlier, there were two stages in this **prototyping approach**: **reconstructing current home settings** and **modifying them**. Although it took time to guide the elderly to recreate an imitation of their home to scale, this process was very useful. The creative exercise was done in the home of the elderly. The facilitator invited the participants to go through the different areas of their home one by one. The elderly could easily refer to their home settings and identify the matching models, position and orientation. This worked well as a rehearsal for the next task. No verbal material was required (except simple oral instructions). Thus, this method was effective for the participants with different levels of language education, as long as they could interact with the facilitator by speaking and listening. After reconstructing their home settings themselves (some participants needed help from the facilitator, such as showing the tasks at the beginning), the facilitator guided them to point out the positive and negative experiences of their current living environment.

Once the main problems or criteria were discussed, the facilitator encouraged the participants to make changes through a trial and error approach until they identified a preferable setting or adjusted the transformation of a new home. The design intent, expectations and/or new concepts of the elderly were collected by recording the changes in the furniture and the voice and notes made by the facilitator.

Figure 4.3.2 This image shows the prototyping process of a male participant over 70 who explored a new furniture layout and selected new furniture and home products based on the configuration of his current apartment (scale model).

Summary of identified problems:

- **Prototyping using predefined modelling materials enabled creative participation:** One of the main problems with **engaging people (or the elderly) with different levels of education or languages** was the consistency of the questioning approach and the uncertainty of the validity of the data, as identical research questions/protocol/tools were used. Second, engaging and empowering the participants is a common concern in the **participatory design approach**. In this case, we realised that the **prototyping process** could be used as a form of **personal journey/experience review** to gain **first-hand learning experience**. The participants were actively involved in the construction of the model (predefined scale furniture models/items) in which learning and reflection could be better articulated by connecting their previous personal experience and the tangible world of their home environment. In particular, the furniture items were common objects that most participants knew or had used in the past. In addition, they could choose and use the furniture (items) without writing or sketching. Therefore, their education level and drawing skills did not affect their performance.

- **Prototyping a familiar space/design enhanced reflection:** Similar to the two-dimensional home design workshop, the method helped the elderly address or criticise the research context (the spatial and furniture design) from a different or a new perspective and their previous memory. As the elderly could review their home environment holistically with a bird's-eye view, they could build a **dynamic and sequential mental image/process**, such as a walk-through or user experience sequence while using the different areas associated with different products of their home. More detailed reflections or opinions could be collected than with a questionnaire.
- **The prototyping process worked as an open research approach:** In general, some irrelevant concepts are worth investigating, as they may disclose insightful or previously unknown design problems and opportunities. Thus, the prototyping process was used as an **open research approach**.

4.3.2 Project reflection

One of the important reflections of this case was the implementation of a **first-hand learning experience in the prototyping process and the open interactions with the participants, the tools and the researcher**. In conclusion, there were **two main types of prototyping processes**: retrospective prototyping and prospective prototyping.

Retrospective prototyping involves reviewing and analysing the context of the study, including refreshing the current situation and recalling memory through a perceptual experience journey while prototyping with immediate first-hand feedback (e.g. react to sight, touch or walk). This process can capture experiences with the current design and trigger previous experiences when interacting with the current design elements.

Prospective prototyping involves imagining a future or non-existent situation or design concept. For instance, the elderly were helped to modify their home prototype to scale (duplication of the real situation) into a preferable one. It helped them create a more realistic new design based on the current design made with a scale model. **Non-professional participants** could also generate or provide concrete and clear expectations or requirements for a new design.

4.4 Case IV: Jockey Club Retreat Workshop 2018

CASE IV
Comparing the performance of younger and more educated participants

This case was an extension of the workshop of Case I (My Quality Home Living – The Elderly Creative Workshop). The Hong Kong Jockey Club Charities Trust (The Club) invited me to lead a training session on design thinking and the use of creative tools to analyse older people's perceptions on 17 August 2018. The workshop aimed to test and review the design thinking method and home design tool used in research on the elderly in Hong Kong. It involved eight group activities and 45 staff (junior and senior) from The Club. The significance of this workshop was that it involved younger and more educated participants than the senior community. The results were expected to corroborate the results of the cases involving elderly participants.

4.4.1 Identification of issues and problems related to early phase prototyping

The workshop was a training session that allowed the participants to experience the prototyping method as a research tool to analyse their preferences for home living conditions. Thus, the exercise lasted only about 45 minutes. Similar to the elderly group, the female participants in this group had more problems with misalignment and misorientation than the male participants. Case II (two-dimensional home design workshop) had the same phenomenon. As the purpose was to experience the creative process, I did not count all of the participants' incorrect placements. However, more than half of the teams misdirected or misaligned the furniture items in the isometric floor plan. In conclusion, the younger generation had similar **visual spatial problems** to the elderly.

From another point of view, this phenomenon (misorientation and misalignment) revealed that **not all of the participants** could deal with complex visual and spatial tasks, experiments or interactions. The **individual visual-spatial reasoning capability factor** affected the assessment and data analysis results.

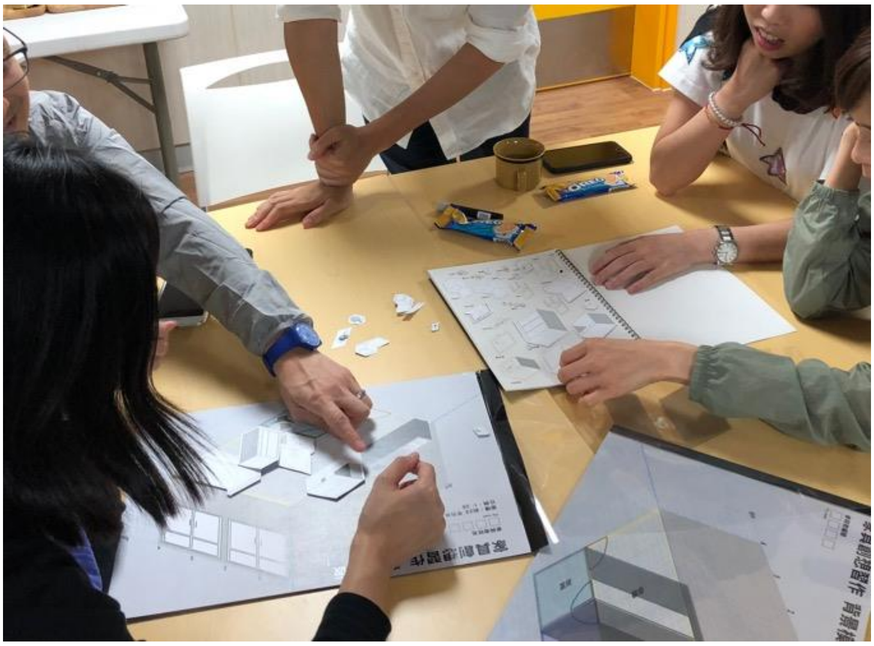


Figure 4.4.1 Four members of The Club collaborated to complete the creative task.

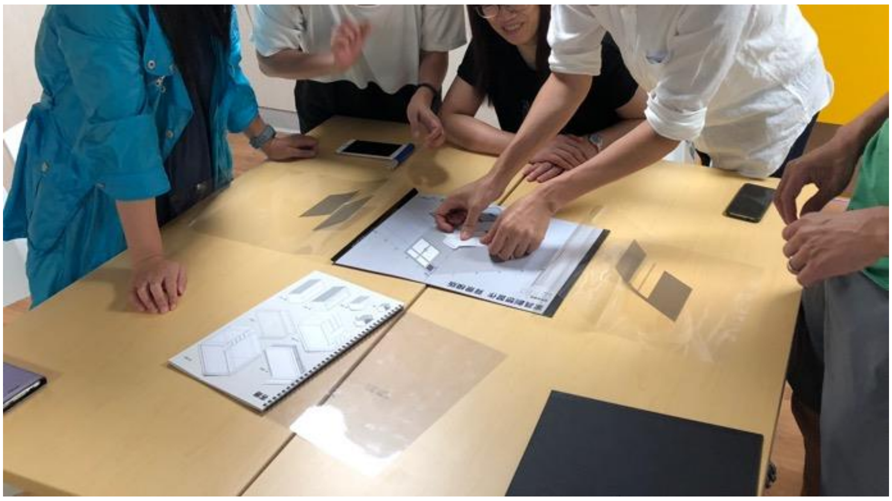


Figure 4.4.2 I informed the team that a furniture item was misoriented. The image shows me illustrating the right position.

Figure 4.4.3 This image is proof that the members of The Club also misaligned or failed to properly orient items during the prototyping process.

Summary of identified problems:

- **The participants showed various levels of performance in visual-spatial ability:** The effects of visual-spatial reasoning problems could be minimised with the help or participation of the workshop facilitator. Some of the participants were better at manipulating three-dimensional objects or images with three-dimensional information. However, others could not manipulate the objects or images correctly, even with the spatial clues.
- **The participants explored the design iteratively:** Many of the teams explored the furniture layout iteratively in an active manner. This was a good sign that the prototyping tool could lead to collaborative work. The scale furniture models and floor plan provided 'realistic' information to the participants who could focus on exploration (trial and error).

4.4.2 Project reflection

Public engagement or co-creation with different stakeholders has become an emerging trend in the design process to promote bottom-up and collaborative actions. If the output of the engagement (e.g. design concept) is closely related to visual language, **the participants' visual-spatial ability** or **performance** is a key concern. The problem is that we cannot be sure that all participants have a high visual-spatial ability. Thus, three-dimensional tools are more effective than two-dimensional visual tools or purely verbal means for investigating visual-spatial reasoning.

However, this case indicated that **collaborative prototyping** was a feasible and effective method. The prototyping tool **supported trial and error** (exploring different possible options) with a small group of people. The results (visual means) could be understood and evaluated quickly by all participants simultaneously. The results were more concrete and clearer, without misunderstanding, compared with a verbal concept that could induce different values or concepts for different people.

4.5 Case V: KODW 2017 Elderly Design Workshop organised by the Royal College of Art

CASE V
Prototyping the user journey/scenario to collect new information

The KODW 2017 Elderly Design Workshop was called 'Design Safari – A Practical Workshop in Design Thinking and Design Doing!' and was organised by the Hong Kong Design Centre (as part of the KODW event) and hosted by The Helen Hamlyn Centre for Design (HHCD), Royal College of Art, on 16 June 2017 in Hong Kong. This workshop was designed to provide continuous education for professionals, including design practitioners, other professionals and civil servants. I took part in the workshop as one of the 40 registered participants. The main objectives of the workshop were to explore different social needs, in particular those of the elderly in Hong Kong, through a people-centred creative process. The process included observation of elderly nursing homes (three elderly nursing homes were visited) and interviews with the participants to explore new trajectories to ideate and create a design proposal through rapid prototyping methods in a short time.

Several practical tools were introduced as innovative approaches to develop appropriate communication, product and service design for social change, such as personas, post-it notes, posters (as a framework to communicate new concepts), user journeys (e.g. experience of a day), scenario creation based on user journeys and collages of relevant images.

4.5.1 Identification of issues and problems related to early phase prototyping

In terms of information gathering and clustering, observation of the typical representation or presentation of people's concepts/minds/experiences was used.

Usually the participants only wrote the concepts via verbal means. In this group, sketching was not used.

Figure 4.5.1 After the site visits, the workshop facilitators asked the participants to write down the problems and opportunities identified during the visits (on-site observation and interviews with the staff of the nursing homes). This photo shows a team member sharing his concepts.

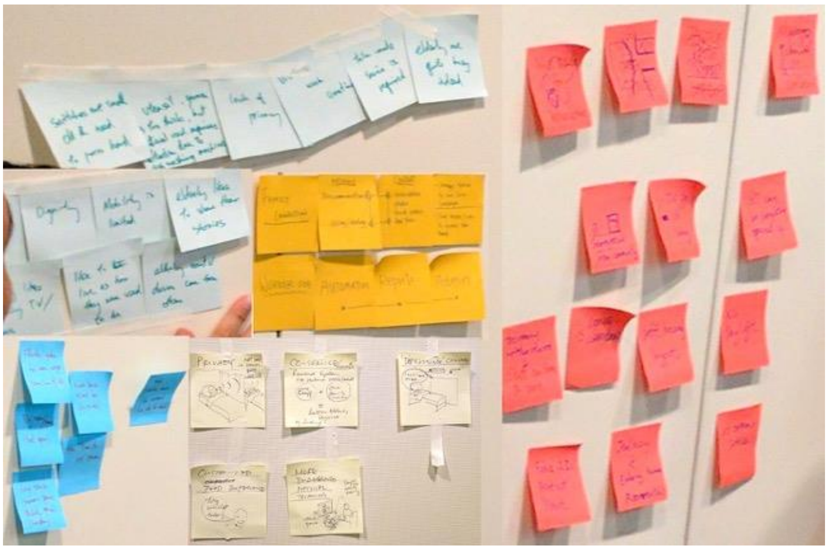


Figure 4.5.2 This image combines the work of five participants. It shows that most concepts written on Post-it notes were based on text. The pale yellow Post-it notes (bottom centre) were mine.

During the brainstorming process, the facilitators introduced the user journey method to the participants to imagine and create the daily experience of a persona. As shown in the sample below, a timeline (24 hours from left to right), corresponding activities (the

Post-it notes at the top of the timeline) and emotional states (happy vs. unhappy) were connected to a scenario prototype. Some images were put on the map to further enhance the stories or the experiences. This method was a good initiative because all of the participants started to integrate their experiences (e.g. observations and stories collected during the visits) in the **framework for holistic consideration** on the daily pattern from the point of view of the elderly. This method was a type of **scenario prototype** in which the participants could co-create an experience with both tangible and intangible designs. In addition, the participants could be more empathetic because of the experiences of a day (awareness of timeline and repetitive practices) and emotional states (awareness of happiness and sadness).

Figure 4.5.3 User journey map to help the workshop participants (designers) imagine the emotional states of a senior living in a nursing home during a day, with the illustrated support chosen by the elderly.

Eight preferable concepts were selected by consensus of the members. The main categories of the new concepts included **(i) new service design** – using facetime to solve overtime; a co-service model with a reward system combining family members and caregivers; building emotional connections; building relationships with the family of the elderly; providing care/love to the elderly; and **(ii) spatial design** – flexible partitions to provide various functions; spatial dividers to increase privacy; and colour coding to differentiate the rooms to avoid getting lost. These concepts included

concepts focused on problem identification (e.g. 'too many rooms and getting lost'), **concepts focused on service solutions** (e.g. 'building new emotional connections') and **concepts focused on product solutions** (e.g. 'a flexible system for room usage').

Some textual concepts were more **concrete** and **easier to visualise or prototype**. For instance, the colour coding solution to help the elderly identify different rooms could create a concrete experience. However, some concepts were more **abstract** and **difficult to visualise**. For instance, the concept of developing the relationships between the staff of the nursing home and the families of the elderly was a clear strategy. However, it was difficult to imagine or find exact solutions or concrete experiences in actual practice. There were many questions!

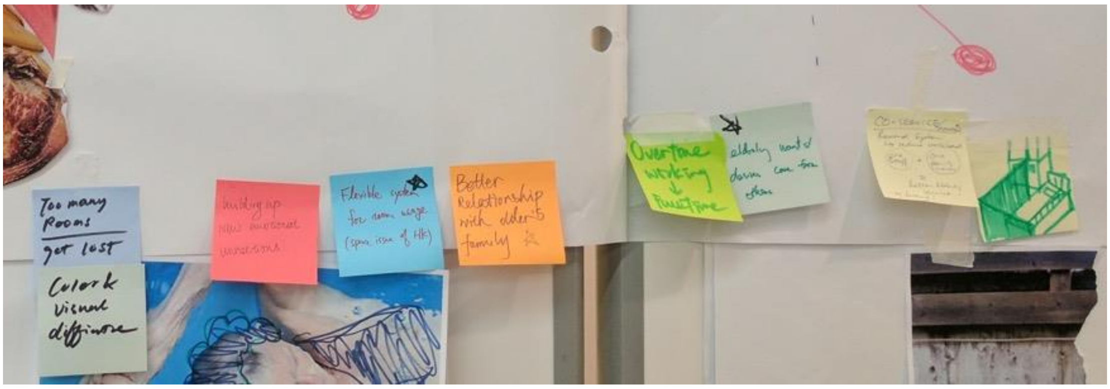


Figure 4.5.4 This image shows the concepts agreed upon by all members.

Summary of identified problems:

- **The user journey or scenario prototyping was an effective tool for integrating concepts generated by a larger group of participants:** The final outcome of the workshop was the user journey (or scenario prototyping).
- **Scenario prototyping helped develop three types of concepts**: Concepts focused on problem identification, concepts focused on service solutions and concepts focused on product solutions.
- **Concepts with concrete actions**: Some concepts (design solutions) were associated with concrete experiences directly or quickly.
- **Concepts with abstract directions**: Some concepts (design solutions) could not be directly associated with user experiences. These were more open with greater uncertainty in actions.

4.5.2 Project reflection

It is obvious that the time factor strongly influences the quality of a design workshop. Most design workshops are short. Workshops lasting from a few hours to one to three days are more feasible, especially if the workshop is conducted to engage community stakeholders or train staff or professionals. Only academic or research-based activities, such as student projects and research projects, may allow long-term participation. In this one-day workshop, the facilitators introduced the methods for addressing service innovation for the elderly, which could be considered as training on the product-service system thinking process.

4.6 Case VI: The Park Lab 2017

CASE VI
Review of a large-scale and long-term process workshop for community stakeholders

Between April and September 2017, the Jockey Club Make a Difference (MAD) Social Lab organised the 'Park Lab' project with the School of Design, The Hong Kong Polytechnic University. It was the first community-initiated public service innovation lab in Hong Kong to improve public park design through community participation, design thinking and co-creation with prototyping. The project team consisted of park managers from the Leisure and Community Services Department of Hong Kong, designers, landscape architects, NGO representatives, community-based youth initiative organisations and Meifoo residents. It was organised at Lai Chi Kok Park in Meifoo, where the government allowed field research, analysis, community co-creation, engagement and prototyping experiments to explore how bottom-up collaborative creativity responded to the needs of local stakeholders. I offered design thinking lectures to all participants and supported the workshop process as an advisor to the other four facilitators who managed four teams of lab members with different goals generated by each team.

To facilitate prototyping for public engagement at the end of the project, the participants carried out several important processes: **site observation**, first-hand **story collection**, **idea brainstorming** and **clustering**, **public presentation**, **prototyping** and **public engagement**. The facilitators incorporated different tools to support the prototyping process, such as the **AEIOU framework**, **scenario study** (Figure 4.6.7) and the **VIPIS framework**, which includes the five elements of value proposition, intervention, programme, infrastructure and stakeholders, modified from the AEIOU and POEMS frameworks by the facilitators of the programme; Figure 4.6.8).

Figure 4.6.1 The Park Lab was the first project of its kind in Hong Kong organised by the Social Lab of Make a Difference, an NGO in Hong Kong. The project lasted five months with 28 members from different disciplines.

Figure 4.6.2 The Park Lab adopted the commonly used 'Post-it' method to collect the concepts of the participants and support concept clustering. The facilitators used this tool to help the participants categorise or organise fragmented ideas. The clustered ideas could inspire concepts from different perspectives, stakeholders, resources, etc.

Figure 4.6.3 The first task of the workshop involved **story collection**. The image above shows first-hand research through observation and questions about the phenomenon. The facilitators expected the participants to **collect information and identify themes** using on-site observations, user engagement, empathy (user-centred perspective), culture and other ways of seeing the practice of people in the park.

Figure 4.6.4 The photo shows how the team members clustered the stories under certain themes.

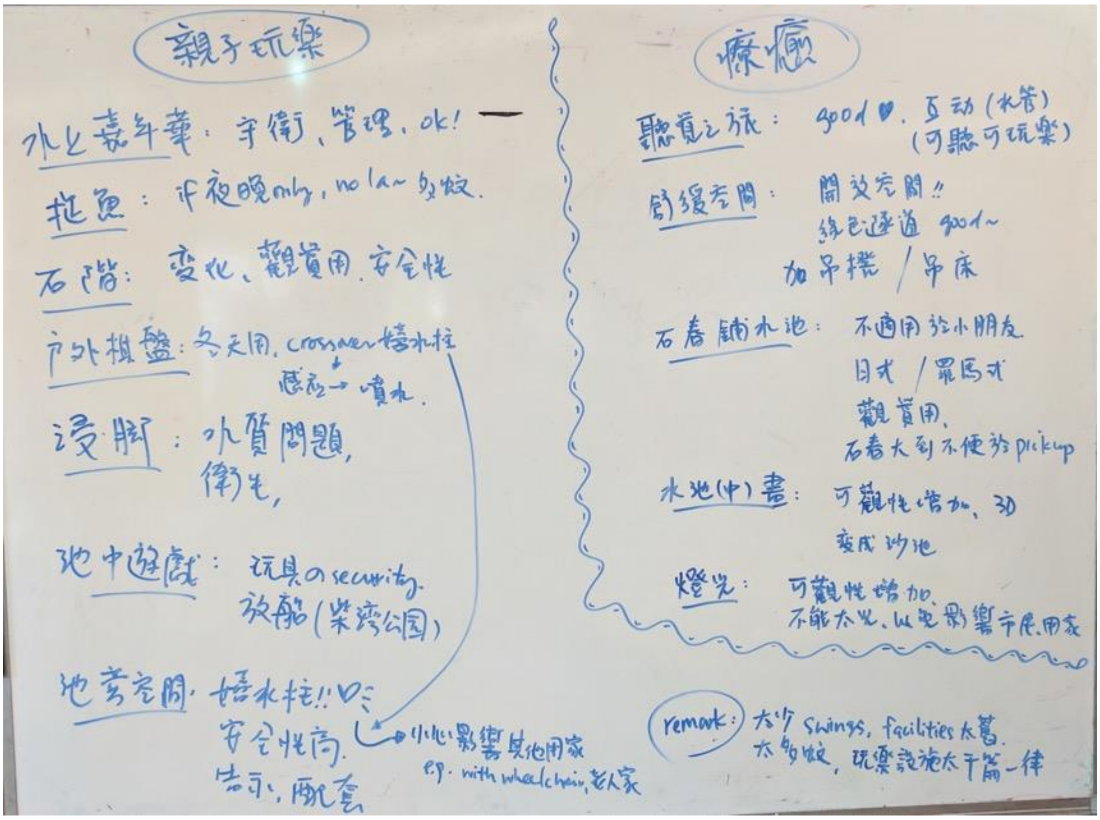


Figure 4.6.5 This image represents the idea brainstorming results of one of the teams. Brainstorming and activity development were the main objectives of the project. The participants were expected to select a feasible concept from the list and to extend it through scenario study during the next phase.

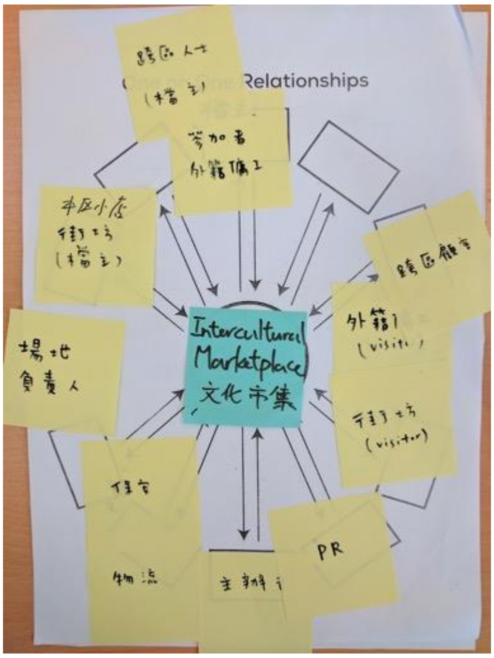


Figure 4.6.6 One of the methods used was a stakeholder map. It was important to develop the prototyping activities as the designers might need to know or be aware of the relationship between design (product and/or service design) and users (all possible stakeholders).

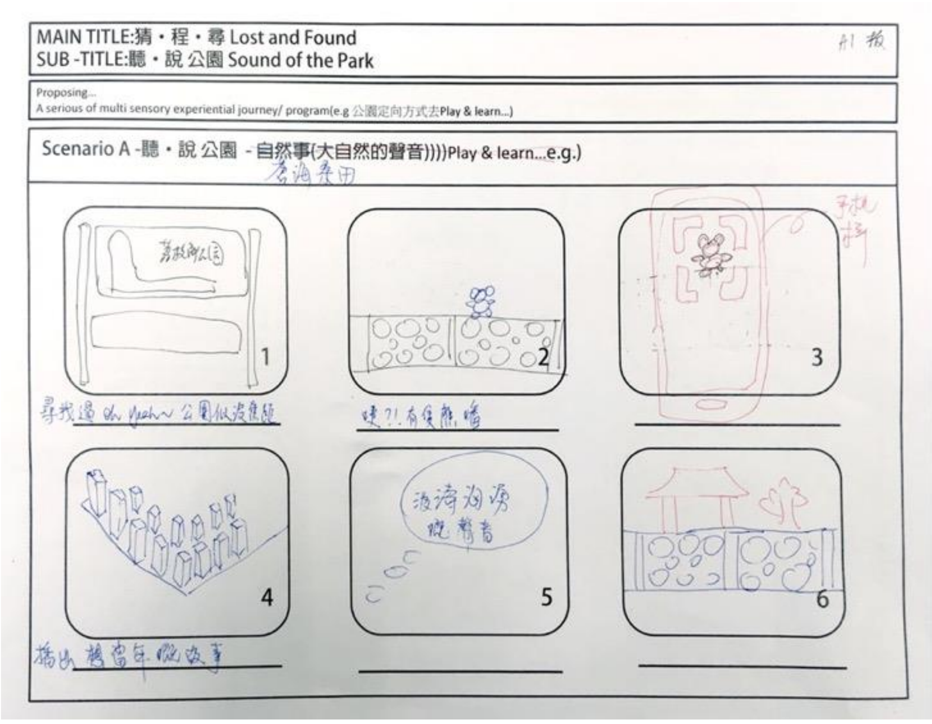
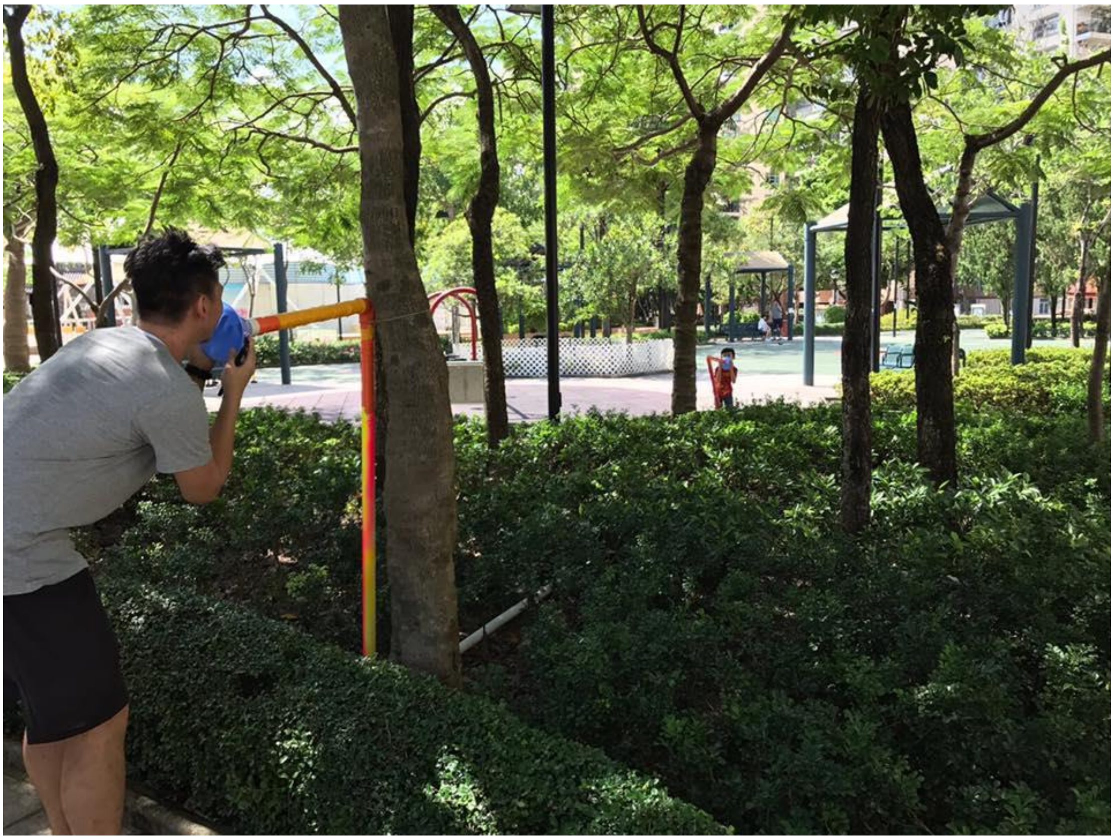


Figure 4.6.7 Scenario study generated by the one of the design teams.

Figure 4.6.8 Based on the AEIOU framework, the VIPIS framework (value proposition, intervention, programme, infrastructure and stakeholders) was developed by the facilitators to help the participants integrate the concepts and prepare the early prototyping process.

Figures 4.6.9 and 4.6.10 These two images show the prototyping process as an engagement method conducted in the park.



Figures 4.6.11 and 4.6.12 The first on-site prototype evaluation was adopted to observe how real park visitors experienced the hypothesis (design).

4.6.1 Identification of issues and problems related to early phase prototyping

Below are some key aspects raised by the other facilitators and workshop members during the debriefing at the end of the workshop.

> ‘It was difficult to encourage the “labbers” to explore ideas from the perspective of different stakeholders. Different methods, such as AEIOU, on-site observations, user interviews, public engagement, were used. However, the **participants’ “experiences”** were limited as they could not be pushed further to adopt the idea of “co-management”’ (emphasised by one of the workshop facilitators and corroborated by the other facilitators).

> ‘It was not easy for us to think strategically until we did a trial …’ (reported by one of the workshop participants)

The concept of ‘co-management’ received positive encouragement from all facilitators. The final outcome of the workshop was to engage the public (e.g. user evaluation or co-creation) with the prototype in the park. Thus, the workshop facilitators focused on empowering the participants (and other stakeholders) to consider all possible details of this new concept to develop it into a prototype. However, in light of the two comments above from a facilitator and a participant, it was difficult to push forward the development of the prototype.

Indeed, it was difficult to **guide the participants to further visualise a holistic picture and produce a rapid prototype of the concepts** they proposed in writing or simple sketches. Why? **One of the possible answers** is that not all participants were good at visualisation and modelling. The lack of appropriate arts and crafts training may limit participation in the prototyping process. **The second reason** may be the articulation of the textual concepts not easily associated with physical experiences or tangible objects. The concept of ‘co-management’ was one of the typical concepts of this workshop, designating an abstract and complex service design rather than a concrete object.

Summary of reflections:

- **Most of the tools used in the workshop were text based:** There was a dilemma: although the development of the prototype required clear visual associations and know-how in materials processing, the facilitators were not satisfied with the design concept.
- **Abstract concepts could not be easily imagined by inexperienced people:** According to the 'co-management' case mentioned above, the facilitators extracted an abstract concept from the analysis with the workshop members and wanted to further develop the concept, including detailed operations through scenario study and mock-up making for evaluation. All members were mature people with a high level of education. Therefore, the facilitators did not expect that the participants could not envision how to develop a design strategy or prototype to implement 'co-management' in the park. The facilitators were frustrated and spent more time coaching the team to realise this concept. At the end of the project, the project team gave up this direction and developed another more concrete but less effective concept (from the point of view of the facilitators). 'Co-management' was a foreign term for all participants, which could be due to a lack of information or a holistic impression of the term. The representation of this concept was too abstract and people could not visualise or identify a relevant image to physicalise it.
- **Prototyping was a learning process for tackling abstract or unfamiliar experiences:** According to Miss K, one of the workshop members, she could not appreciate and adopt the complex concept (design solution) holistically until she engaged with the prototype and other real users. It can be concluded that a prototype is useful not only for visualising or physicalising an abstract concept for user engagement and evaluation, but also for building more concrete learning for the participants to experience or envision a new concept.

4.6.2 Project reflection

Prototyping as an approach or technique was more challenging than most designers and design educators expected while planning and running a design workshop for design-trained people and novices. This reflection offers a significant insight into a dilemma. Workshop participants may not be able to prototype an abstract concept and may avoid it if they find it difficult to envision or lack self-confidence to pursue the concept.

However, no prototype or a low quality prototype may also fail to stimulate the learning experience of the participants. Thus, it is necessary to push the realisation of prototyping. According to the literature review, the ‘imageability’ of a verbal concept is highly affected by the ‘concreteness’ of the verbal means used by the workshop participants. The higher the ‘concreteness’ of the verbal concept, the higher the ‘imageability’ of the design concept to allow communication and articulate the prototyping process.

4.7 Case VII: PolyU x HHCD Healthy Ageing in Hong Kong: Hong Kong Care Homes

CASE VII
Review of a project with different professions and visual tools

This case was a three-month workshop called PolyU x HHCD Healthy Ageing in Hong Kong: Hong Kong Care Homes. The Helen Hamlyn Centre for Design (HHCD) of the Royal College of Art and the School of Design of The Hong Kong Polytechnic University (PolyU) were the co-organisers. The project aimed to generate exemplar research to inform design ideas for the development of new elderly care homes in Hong Kong. The study focused on how elderly residents in Hong Kong engaged and experienced their 'home' and 'care home' environments in the contexts of minor care and end of life care. I was involved as a workshop participant and partially supported the research and design processes. The study analysed the cognitive, visual, auditory, mobility and dexterity aspects of older people in Hong Kong. The project ran from September to December 2017.

According to the HHCD methodology and schedule, the four stages of the creative method (Discover, Define, Develop and Deliver) were conducted for 10 weeks with the following indicative activities. The **Discover phase** included i) desktop and background research; ii) review of previous healthy ageing projects; iii) identification of new research areas; and iv) initial user observations and interviews, such as on-site visits to elderly nursing homes and service centres. The **Define phase** included analysing the users' observations and interview results, developing and testing the hypotheses (initial phase prototyping), mapping the disability trade-off and formulating design directions (scenario/service design prototyping). The **Develop phase** further developed the design directions, concept models and user scenarios (scenario/service design prototyping). The last phase was **Deliver**, during which the outputs of the previous work were finalised and illustrated for communication (called 'design communication package'). Finally, the agreed project outputs were disseminated through a presentation and an exhibition.

4.7.1 Identification of issues and problems related to early phase prototyping

I was involved in the on-site visits (two elderly nursing homes) and a one-day design thinking workshop attended by more than 30 participants, including academic staff, graduates and undergraduates from the School of Design and other disciplines, such as nursing and social sciences. Some important notes were introduced at the beginning of the workshop. As in other workshops, everyone was assumed to be creative and was expected to create things together. In addition, design thinking was conducted hand in hand with design doing. The four-stage double diamond design process model, from convergent to divergent thinking (discover, define, develop, deliver), was introduced. As usual, the early prototyping activities took place during the Define and Develop phases. In addition, the facilitator prepared images or methods as design tools to spark imagination and communication, such as scenario study.

Figure 4.7.1 Scenario study generated by the one of the design teams.

After the on-site visits to the nursing homes and a brainstorming session, the workshop facilitator recommended three directions: **(i) the needs of less fragile seniors for a user-friendly bed design** in nursing homes; **(ii) older people who can enjoy social interactions in public areas** in nursing homes; and **(iii) more agile elderly who can participate in the community** to receive appropriate home care services. Some concepts were generated to respond to these three areas: design concepts focused on the **transitional space** for everyday experiences (e.g. old photos or stories to stimulate the cognitive ability of older people), **connection to the community** (e.g. design to support outdoor and indoor group activities) and **community network to integrate the experiences of most stakeholders**.

Although the three design directions were sensible and the concepts were useful, this does not mean that these common concepts were part of the workshop's objectives of seeking insightful concepts that could bring new ways of thinking, practising and/or a paradigm shift. This workshop followed a design process similar to other workshops and high fidelity prototypes were proposed (two- and three-dimensional examples), such as a new self-contained bed design for nursing homes, a set of dishes and utensils as assistive eating tools for the elderly and a system design to make life easier for the elderly. A final presentation and an exhibition were organised to celebrate the end of the project. During the three months of the project, there was no other user engagement through prototype testing and no participatory design section. In other words, this project undertook a conventional product development process: the final prototype was offered at the end of the process.

Summary of identified problems:

- **User research could not guarantee appropriate or creative insights:** The workshop offered good on-site observations and interviews with users and stakeholders. However, observing or analysing current problems and phenomena may not offer creative insights for the designers or researchers to solve these problems. Yet the in-depth study took a lot of time and resources and could not ensure the generation of new concepts. Thus, the creative thinking tools or approaches used were essential. The experiences and interpretations of the designers and researchers were also important.

- **No early prototype testing limited the possible solutions or creative concepts:** Most designers and researchers recognise that prototyping is an effective approach to stimulate and collect design information. Unfortunately, in this case, prototyping integration was not well implemented until the end of the design process.

4.7.2 Project reflection

As previously mentioned, in my experience, most design workshops seek to explore new concepts or solutions to current problems through human-centred research. Most facilitators always emphasise the importance of prototyping, which is a crucial part of a workshop's outcomes or deliverables. Based on my observations and reflections, there were two challenges: the **on-site visit and idea brainstorming approaches only offered minimal progress** and the workshop process without **early prototyping testing could not support the exploration of new assumptions and/or the stimulation of creativity**. It would be useful to understand why early prototyping testing is never undertaken in the early process and why prototyping is perceived as a method for generating creative concepts or solutions that can supplement in-depth human-centred design research.

4.8 Case VIII: Intergenerational Game Design Workshop with and for the Elderly

CASE VIII
Co-creation with stakeholders in the initial and final product evaluation phases

This case described a four-day co-creation workshop, which was the first stage of a creative initiative organised by the Hong Kong Christian Service Integrated Home Care Service and the School of Design of The Hong Kong Polytechnic University that led to a one-year intergenerational board game project with prototype development, testing and evaluation processes. The project aimed to mobilise older people living in poverty, hidden elders and/or older people living alone or with their spouse only through home services with a playful interaction strategy. The project sought to explore what types of board games and how they could enable higher quality interactions in the local context and with respect to local seniors. The games (prototypes) were assumed to enhance services for the elderly with no family support and no access to normal social interactions and the service network of the community.

Twelve active and young-old participants were recruited as elderly designers to work with six design students and two design academic staff (workshop facilitators). I was one of the facilitators. Intergenerational play was introduced in the home services where 20 volunteers, including active seniors, youth and women, were trained to deliver the 'play' service to the elderly. The prototypes (four co-created board games) were used to successfully engage 80 service recipients in early 2019. This case study focused on the aspects of the prototypes (board games) as a research approach to people's comments.

4.8.1 Identification of issues and problems related to early phase prototyping

In this workshop, four full days of co-creation were organised. The 18 participants (young-old and design students) worked collaboratively to explore the game context to match the interests of local seniors (e.g. familiar game types, stories or daily scenarios). The brainstorming exercise included the three-zone mapping of the seniors' preferred activities (as shown below). The young-old participants found this exercise easy, as user-related activities could be recalled and described based on past personal and concrete experiences. This was usually shared with the other participants.

Figure 4.8.1 The three-zone map helped the elderly participants to brainstorm their preferred activities between the three zones: home, community and travel.

In terms of prototyping approach, the workshop introduced **four types of game modes**: **competitive games, opportunity-driven games, role play games and body interaction games** (e.g. eye-hand coordination). The facilitators asked the participants to quickly write or draw the play activities covered in these four types of games. The criteria for concept exploration and development included the **elements, role, noun, verb and adjective of the play activities**. This method encouraged the participants to explore in detail the experience of game design (as shown in the photo below). These five criteria had the same objective as the AEIOU (Activities, Environment, Interactions, Objects and Users) or POEMS (People, Objects, Environments, Messages and Services) frameworks for idea brainstorming. After clustering the five groups of concepts, the participants integrated the results based on the four directions with four different purposes of game design, covering the empowerment or enhancement of socialisation, eye-hand coordination, cognitive stimulation (e.g. memorise concepts and recall them) and spiritual well-being (see Figure 4.8.3). More importantly, in this project, these criteria **focused on the stimulation of a single person**.

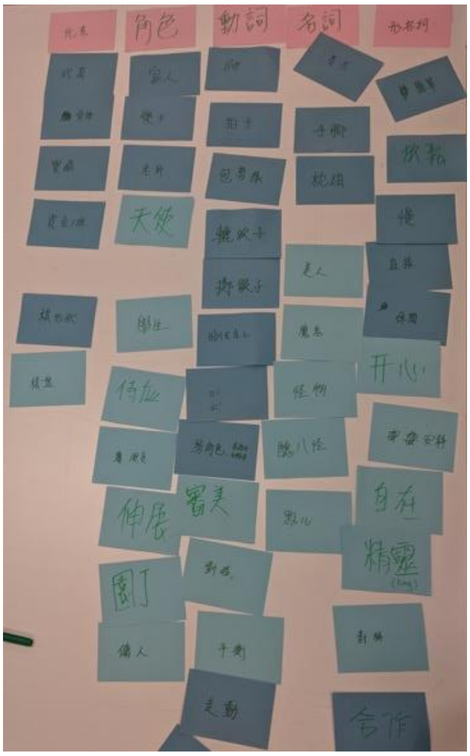


Figure 4.8.2 The facilitators instructed the participants to quickly write or draw the play activities covered in the four types of games. The criteria for concept exploration and development included the elements, role, noun, verb and adjective of the play activities. This method encouraged the participants to explore in detail the experience of game design. As shown on the left, the five clusters of concepts showed the co-creative inputs of the young-old and the students.

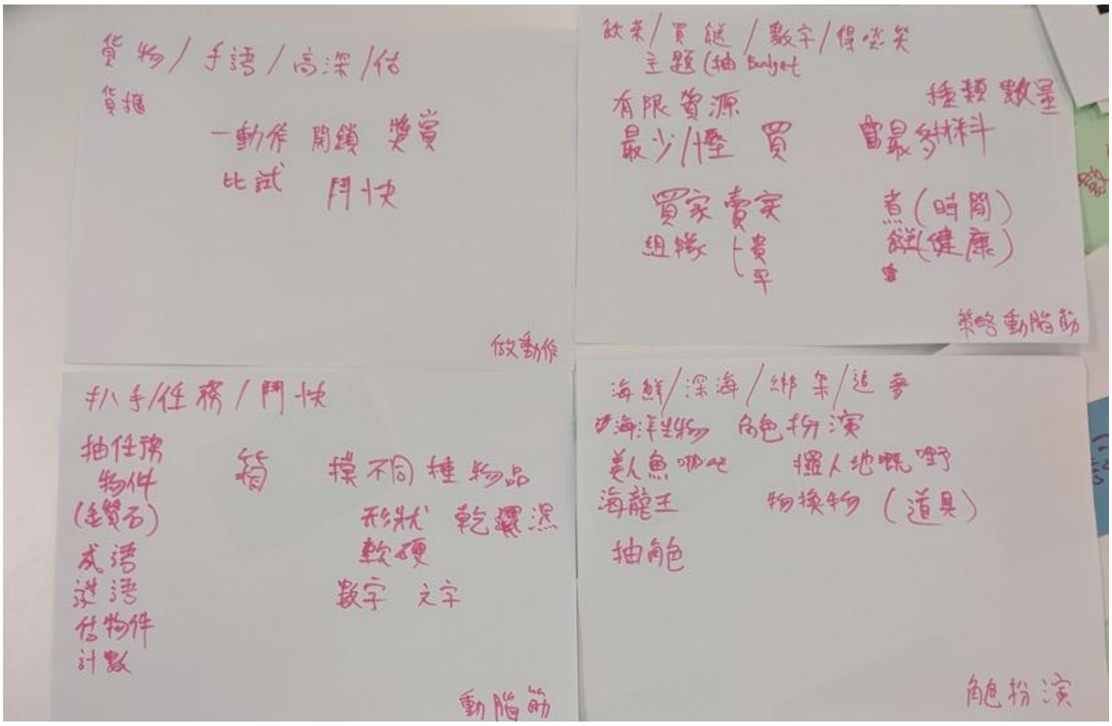


Figure 4.8.3 This image shows the output of one of the teams, covering the four directions of game design: empowering or enhancing socialisation, eye-hand coordination, cognitive stimulation (e.g. memorise concepts and recall them) and the spiritual well-being of older players.

The main problems were clearly defined and some areas were set before the implementation of the co-creation and engagement activities. It was easier and more effective for the facilitators to frame the workshop activities and derive the final prototype for analysis, for instance the evaluation of the prototype (assumption), which usually cannot be done with a questionnaire alone. This may explain why the prototype was the first priority of the workshop and early phase prototyping was carried out.

Investigating how and what types of intergenerational play could reduce the loneliness of the elderly could help the designers and social workers introduce innovative and appropriate home services.

Summary of identified problems:

- **A clear framework led to earlier prototyping:** As discussed earlier, this workshop with a clear service scope enabled early prototype development. In short, early design assumptions helped the workshop participants identify the possible directions and develop the first prototype for user evaluation.

- **A range of prototyping activities, from a simple scenario** (single person experience/single product system) **to a complex scenario** (collective experience of people/product-service system involving various levels of stakeholders): Compared with a similar case in this thesis (Case VII), this project developed a prototype for public engagement quickly with a clear framework, but also with less uncertainty than the design project to solve nursing home problems, in which the prototype could be a product-service system or a design related to NGO management. In comparison, this board game for the elderly was simple and met the experience or needs of a single person. This experience was embodied in a single entity or a simple small system (such as a game with simple rules and promoting only a few values). A larger product-service system, such as bed design for nursing homes, required the correlation and enhancement of the users (with different physical and mental states) and the service system or business and service model of the nursing homes, involving interactions with service providers and family members.

4.8.2 Project reflection

This project was a useful case to indicate why some projects could not deliver prototypes easily and earlier. The range of prototyping activities from a single user to multiple stakeholders and from a **simple to a complex scenario or system** was worth noting. The factors affecting the elderly game design prototype covered three levels of goals: **i) personal goals** (e.g. personal interests, user experience); **ii) community, cultural or social contexts** (e.g. game contexts, everyday life scenarios); and **iii) management goals** (e.g. social worker agenda, such as community engagement, volunteer empowerment, government policy). These three levels helped the researchers and workshop facilitators analyse and plan the prototyping activities more efficiently.

4.9 Case IX: WeDesign – Young Designer Community Partnership Programme 2018

CASE IX
Application of quick and final prototypes with minimal user participation

The project was an educational programme organised by the Hong Kong Council of Social Service and co-organised by the School of Design and the Design Institute for Social Innovation of The Hong Kong Polytechnic University between May and October 2018. It was a large-scale engagement involving **100 students** who participated in the basic training on design thinking and user research. Then, **40 students** among the 100 candidates were nominated as community designers to help explore and prototype unique and useful furniture to meet the needs of **32 grassroots families** and innovative community services for **two community public spaces**. I participated as a workshop tutor and offered design thinking training and tools to support concept generation.

This case demonstrated various uses of prototyping at different stages. The project explored the design of furniture used in small apartments and portable installations providing community services in public spaces. Cardboard prototypes to fully functional prototypes were produced to inform design improvement, user evaluation and communication.

4.9.1 Identification of issues and problems related to early phase prototyping

The design teams were organised to conduct home visits to selected grassroots families. The aim was to co-create useful furniture with and for the family members. Two to three home visits were made. The family members expressed their needs and expectations to improve the quality of their furniture design during home interviews. In fact, most real users were only involved at the beginning of the research phase and some design teams presented their new concepts with a quick mock-up to the families in their homes. Thus, the participatory design approach was not well implemented in the design process.

Figure 4.9.1 The student designers visited the house of a family living in a small apartment. They asked the mother what were the most pressing issues in terms of living improvement.

Figure 4.9.2 The workshop facilitator realised that the student designers were unable to choose the appropriate dimensions of furniture design. This may have been due to their lack of professional training and no prior experience of furniture design. In this photo, the student was encouraged to make a quick mock-up to provide first-hand

experience of the proposed furniture design concept. A refined mock-up was brought to the family home for demonstration and evaluation with the family members.

Figure 4.9.3 Two student designers reviewed their furniture design with computer visualisation and planned to create full-size cardboard models for evaluation.

The students with design training or software skills tended to use computer drawings to visualise the concepts without a clear mental understanding of actual dimensions and proportions. Thus, the facilitator worked hard to help the students make cardboard/corrugated board furniture mock-ups for a more concrete first-hand experience and a more realistic evaluation than with a computer. The mock-ups also helped understand the structures, enabling the creation of the final prototypes. In this case, the mock-ups played an important role and successfully enriched the appropriateness of the design and the confidence of the design team.

Figure 4.9.4 The full-size cardboard bookshelves were created for evaluation by the design team.

Figure 4.9.5 This paper card furniture system to scale was produced by the students. This prototype helped the designers further clarify the relationships and properties of horizontal planes and vertical planes. For instance, how the shelves should be arranged and how they relate to the location or orientation of other boards (or other furniture components).

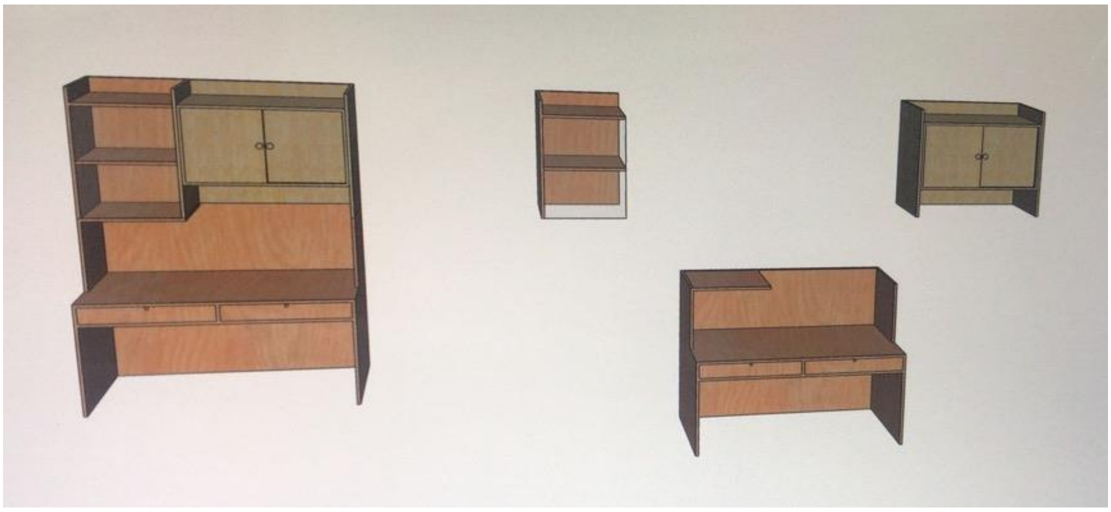


Figure 4.9.6 The students could not produce the final fully functional furniture (first functional prototypes) themselves. The final furniture concepts were visualised with a computer and were used to communicate with professional furniture makers. The organisers expected the furniture prototypes to be durable and usable by the grassroots families.

Figure 4.9.7 This photo shows one of the final working prototypes presented at the programme’s exhibition in December 2018. The furniture was then delivered to the household.

Summary of identified problems:

- **Incomplete participatory design approach:** Inviting or incorporating real users into the design process or even into the main stages was difficult. In principle, combining a design team with real users as teammates was a perfect scenario. However, this case was challenging because i) the participants were not familiar with co-creation/participatory design; ii) they were not available because of their work; and iii) the schedule of the students was also a concern as it was not easy to find a common date because the students came from different institutes and disciplines.
- **The participants (students) lacked concrete and precise experience in furniture design and materials processing know-how:** The lack of understanding of the targeted design contexts hindered the production of the prototypes. In this case, quick mock-ups were helpful in advancing the design.
- **There were obstacles to prototyping:** From the perspective of the resource, although prototyping was essential to the success of the innovative concepts, it was still challenging due to various factors, such as the **professional level in the design and manufacture of prototypes**. However, this was contrary to the

spirit of the participatory or co-creation design approach. Were there other reasons?

4.9.2 Project reflection

This workshop had two objectives: to empower underprivileged families and students and to promote design thinking and quality of life of grassroots communities. Therefore, education and the social mission were the first priorities. Therefore, it focused on a complete design learning process, such as a human-centred approach, and design iteration. This project was very pragmatic (e.g. to create functional and durable furniture) and no significant innovative solutions were explored. Although the facilitator introduced the AEIOU framework for organising and brainstorming ideas, the students did not apply it. The main reason is that the students directly encountered the design problems in the users' homes and collected immediate feedback from them. The co-creation process took place when the users interacted with the students. A mutual agreement was reached quickly. The students also brought their mock-ups to the users' homes to illustrate their prototypes and enable them to discover the features and express their concerns. The prototypes helped **create a dialogue** between the designers, the users and the design.

4.10 Case X: Workshop for Community Service Platform Planning (Yi Pei Square Community Space)

CASE X
Common practices of social workers in designing new services

This case was a special initiative to promote social innovation in a unique community space in Hong Kong called Yi Pei Square in Tsuen Wan. The project started in mid-2016 and brought together academic representatives (the Department of Applied Social Sciences and the School of Design) and NGOs (such as Hong Kong Women Workers Association, Caritas Social Work Services, St. James' Settlement and Concerning CSSA and Low Income Alliance).

To develop the service design of a new community platform, it was essential to map out the missions, capabilities and assets of all stakeholders and to define a mutually agreed framework for the exploration of service design prototypes. The design workshop was organised in June 2017 and lasted approximately two hours. The standard 6Ws method (who, what, where, which, when and why) was adopted to organise and correlate the missions and services of the four main stakeholders. This method is effective in mapping out the different values, missions, activities and resources of different stakeholders. It illustrated their similarities and differences so that the project manager or organiser could plan ahead the prototyping strategy and make a clearer and more resourceful decision that corresponded to different needs. This was important for the prototyping process and for meeting the needs of multiple stakeholders, connecting common goals, appreciating the perspectives of others and building ownership.

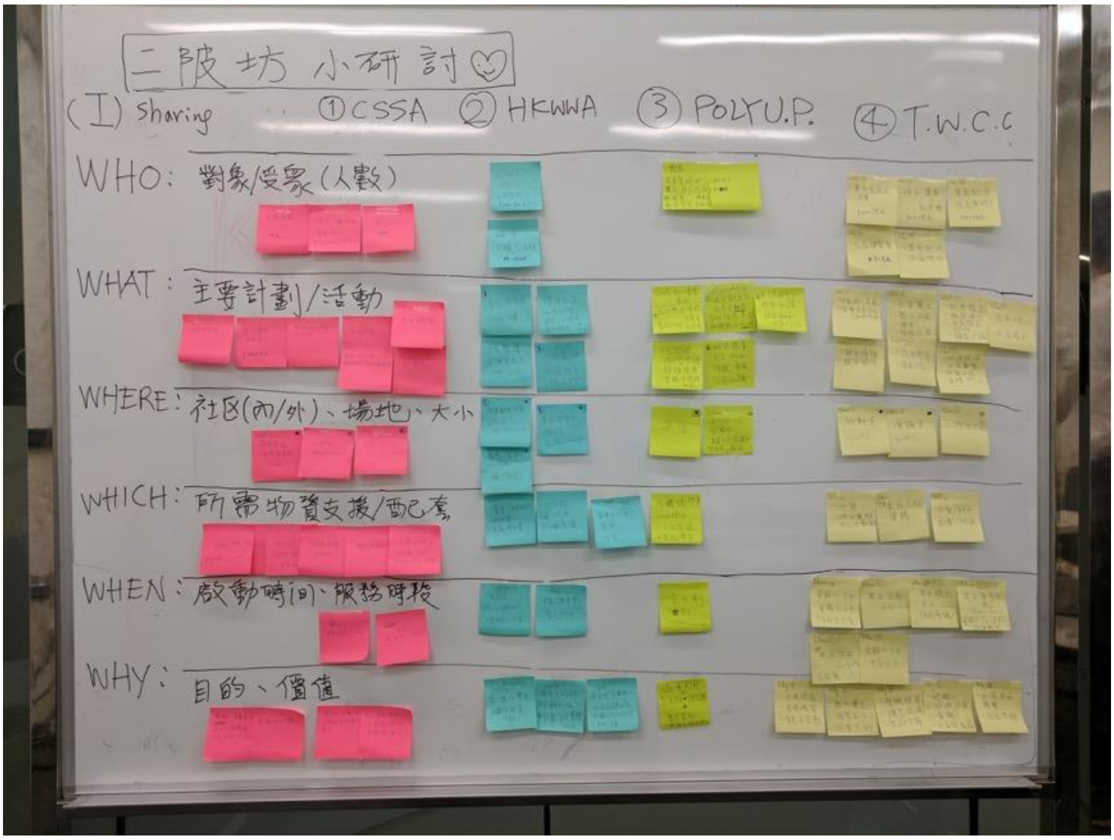


Figure 4.10.1 This image shows the mapping of the four key service providers on the future services they would like to implement in the Yi Pei Square community. The details of the service plans were developed based on the 6Ws descriptors.

4.10.1 Identification of issues and problems related to early phase prototyping

The review of the outputs of the social workers (Figures 4.10.2 and 4.10.3) revealed two main issues affecting early phase concept prototyping activities. First, the workshop participants articulated and explored ideas through verbal means. They were well educated social workers with experience in idea generation. The Post-it method and the 6Ws method worked well. No special instructions were required during the process. The descriptive outcomes, in particular the title of the new activities, were generally clear and significant for the project.

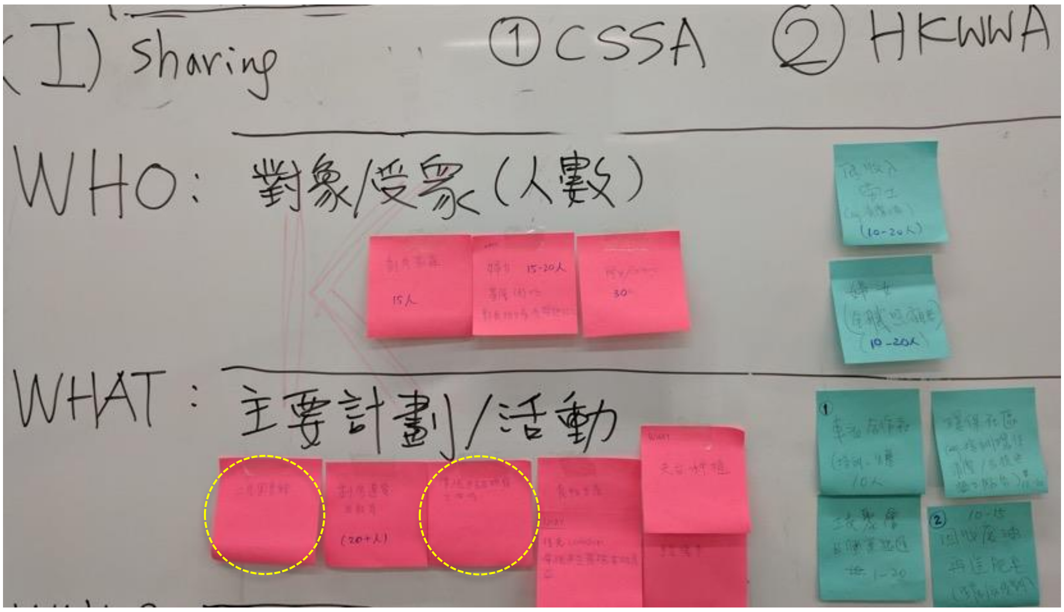


Figure 4.10.2 Focus of the main activities (WHAT) brainstormed by the NGOs: the verbal descriptions were clear and the concepts of the activities aligned with the missions and values of the NGOs.

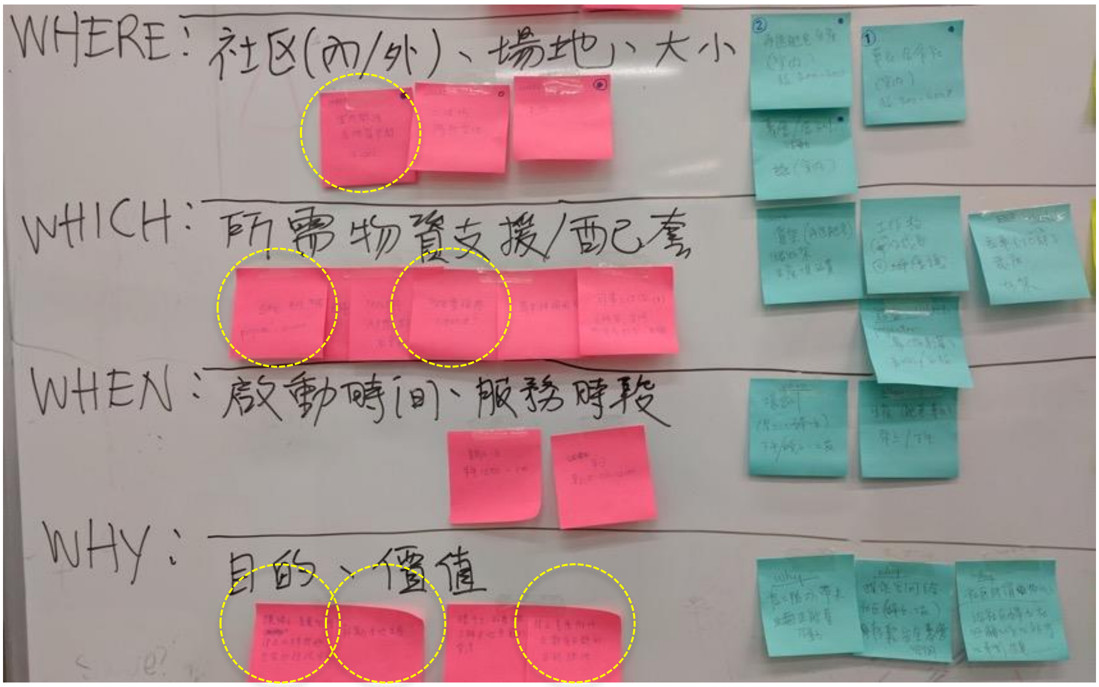


Figure 4.10.3 Although the project titles were clear, they were underdeveloped, such as the 'Tool Library' (工具圖書館) and 'Craftsmanship R&D Workshop' (傳統手藝及研發工作坊). The social workers mentioned the basic requirements for the size of the space (e.g. an area for 15 to 20 people) and generic objects to support the activity (e.g. a writing board, tables and chairs). Nothing related to the 'tools' or 'crafts' was mentioned.

Summary of identified problems:

Overall, the descriptions of 'where, which, when and why' did not help the participants or other audiences envision the activities in a clear and detailed manner. The main problems were as follows:

- **Lack of description of objects or services:** Clearly written concepts did not lead to the easy or explicit launch of the prototyping process. From the data, it was observed that there were no concrete examples or information on the contexts of the activities, for instance, what types of tools will be offered in the 'Tool Library'? This service required basic research on the needs of the community. Another query, 'what types of craftsmanship will be offered in the workshop?', also affected the prototyping of the 'Tool Library'. This case did not provide enough information on the types of objects and could not help the workshop participants further explore service prototypes and spatial design.
- **Lack of details about user experiences/interactions:** The Post-it method also did not provide detailed evidence of the **description of user experiences and interactions** with the objects. These were crucial elements for the topic. For instance, the **service system design** was ignored. How will users sign up for the service, access all possible tools, such as the display method of the tools, and ask to borrow tools from the 'Tool Library'?

4.10.2 Project reflection

The social workers were satisfied with the results of the co-creation of the Post-it mapping, which reflected most of their thoughts (intended service design and most relevant elements) during the two hours of the workshop. All of the participants mentioned that the current outcomes lacked detail for further exploration of the proposals. Another round of meetings or workshops should be organised in the future. Obviously, a two-hour activity was not enough, but it reflected the fact that there was a **potential need** to develop a **more effective co-creation strategy** for short workshops, which could support collaborative conceptual prototyping in a relatively **fast process**.

The Post-it and 6Ws categorisation methods used in this workshop are commonly used. Why do we use this method? One of the reasons is that it is convenient and easy to prepare. Another advantage is that the 6Ws are understood by most educated people. Other methods, such as the AEIOU or POEMS frameworks, are possible, but they are more suitable for conducting workshops with some foundations or basic elements beforehand. The AEIOU framework provides information on user interactions to explore the relationships between activities and interactions, while the POEMS framework helps analyse service design if the transmission of a message is essential for the project. Conversely, the 6Ws method is used to comprehensively explore the types of elements, factors and/or items that contribute to the design concept. It makes sense to first **create common ground** (e.g. select resources or elements) for all participants who can use it for the second design stage – the **early concept prototyping phase**.

In addition, to construct appropriate and saturated information to support quality prototyping activities, the 'How' question can be incorporated into the 6Ws method. For instance, the facilitator can introduce the question 'How are the user experiences involved during interactions with a particular design?'.

The main constraint of this workshop was its limited time, preventing the participants from further developing their written concepts, either through verbal or visual means. In addition, the facilitator did not remind the participants to expand the details of their concepts.

4.11 Case XI: Elderly Service Design Workshop for Integrated Services Team

CASE XI
Review of a short workshop on holistic elderly services in a conceptual framework

The holistic brainstorming/asset/concept mapping approach, for instance the aforementioned tools AEIOU, POEMS, VIPIS and 6Ws, can help workshop participants explore observable concepts and personal experiences in a comprehensive framework. However, these tools cannot ensure effective exploration to address a particular strategy or value proposition. It is also more difficult if the workshop duration is very short. I planned and participated in numerous workshops on exploring innovative concepts to solve or improve the lives of older people (indoor and outdoor). One of the drawbacks of implementing the standard design thinking process using Post-it notes (to collect and map participant inputs) and holistic concept mapping tools is that workshop participants spend most of their time mapping out the elements and dealing only with the general situation or the generic problems at the beginning. Strategically, I realised that the standard tools may not **allow the participants to discuss, reflect or explore specific strategies or values** regarding (i) client missions or visions (e.g. NGOs/service providers), (ii) specific research questions or problems (e.g. improving the quality of life at home) and/or (iii) aspects in a specific perspective (e.g. addressing a theory).

This was a small-scale pilot study involving few senior managers in an elderly day care centre providing integrated services to seniors in a local community. This case contributed to the **review of elderly service activities** using another quality of life framework that was expected to produce a range of concepts from simple actions/tasks/scenarios to more **complex scenarios**. Reviewing current and future activities (or service design) is a typical exercise in most co-creation workshops. This type of case study (reviewing activities) may inform the understanding of the relationship between activity creation and early prototype development.

The more complex the design scenario, the greater the possibility of overlapping more workshop objectives. Here, the workshop participants generated **service design concepts** based on a **framework of three interconnected values**: **being, belonging and becoming (3Bs)**. The co-creation 3Bs mapping revealed what concept was simple (one criterion, such as only 'being') and what concept was complex (more than one criterion, such as integrating 'being', 'belonging' and 'becoming'). This study also determined whether the characteristics of the concept (1B vs. 2Bs or 3Bs) were correlated with **'easy to prototype'** or **'difficult to prototype'**.

In terms of elderly services in Hong Kong, one of the main service models is the integrated elderly service centre, which offers a variety of day care services to seniors living in the community. The centre, similar to most community service platforms, is attached to a community, such as a public housing estate, and is built on the ground floor of an apartment complex. It targets older people living in the same area and neighbouring communities.

I used the conceptual 3Bs mapping model to support the visualisation of all services provided by the two workshop participants, who were social workers at the senior management level of the Lok Man Alice Kwok Integrated Service Centre in an old estate of Hong Kong since 1975 offered by one of the biggest NGOs, Hong Kong Sheng Kung Hui Welfare Council Limited. The manager of the centre (monitoring the elderly community services in the public estate Lok Man Sun Chuen) and the service director (managing the regional services of several districts in Hong Kong, including Kowloon City, Ho Man Tin and To Kau Wan at Hung Hum) shared with me their concerns about improving current services and mentioned several emerging challenges:

i) **Innovative services are in high demand with limited resources,** such as manpower, space, expansion of types of services, demand for individual needs and the pressure on the continued development of new knowledge, products and services in the elderly market, as the scope of services has been expanded over the years. Social services have become more diversified but include professional knowledge.

ii) **Lack of space** to support the variety of services for the elderly in the current day care centre. The use of public space is restricted and a change of policy is required.

iii) **Difficulty reaching older men** and **elderly people living alone**.

iv) **Anticipating that the young-old and new older people will need different products and services in the near future.**

I provided two questions to initiate the mapping exercise. The participants were asked to write and map **all current services** using Post-it notes in the 3Bs diagram. The second question was to identify and write about **the type of indoor services that could be extended to the public space using Post-it of a different colour**. The process was quick and smooth as the participants were familiar with the concepts.

Figure 4.11.1 The map illustrates the three conceptual values that respond to the quality of life of the elderly. The three circles represented 'being', 'belonging' and 'becoming', which overlapped.

4.11.1 Identification of issues and problems related to early phase prototyping

The analysis of the distribution and concepts shed light on **early prototyping development**, in particular **improving the iterative design process**. The social workers commented that this exercise was very helpful, as they never mapped their services according to the quality of life of the elderly. In addition, the positioning of the different sectors inspired them to reflect and explore current and new services. How does mapping support the prototyping process? From this case, three key aspects were identified.

First, **the mapping tool highlighted the focus of current social services**. In this case, the map successfully helped the managers identify and review the overall picture of their services in terms of the quality of life of the service recipients, with the activities contributing to being, belonging and/or becoming. With regard to a similar categorisation process, the **AEIOU or POEMS framework** is used to comprehensively explore the components or factors of the system: **deconstructing the target system or scenario**. The **conceptual diagram on the categorisation of people values,** such as the 3Bs model, provided a perceptual framework for clustering the concepts based on the values or concerns of the researcher and designer. Wicked concepts/activities could be positioned and compared with other concepts. The clusters could **inform the strategic direction and positioning of the design**. Different from the component deconstruction model (such as AEIOU), the conceptual value differentiation model provided a global review. This could complement the missing part (which could be the most essential input) that the AEIOU or POEMS frameworks cannot address. In addition, a holistic exploration could be carried out. Thus, to **understand and supplement both verbal concepts** (abstract concepts) and **tangible concepts** (concrete experiences), the process enabled a group of participants to mutually agree on abstract concepts or other implicit experiences. This type of exercise explained a significant aspect related to concept framing, strongly inducing a **positive prototyping ability**.

Second, this tool supported **collective input and analysis**. Similar to AEIOU or other frameworks, it could not only enable group reflection or research on a particular study area (such as the focus on 3Bs), but could also enhance **participation and ownership**.

In fact, I realised that the participants (colleagues from the service centre) with different roles in the organisation could also co-create the map by connecting the ideas from bottom-up and top-down. Thus, this approach was an effective method when **implemented at the beginning of the prototyping process**, to ensure **constructive participation in the latter stage of the design process**.

Third, a comparison of the characteristics of the three zones revealed a distribution of the **complexity of the actions (activities)**. First, in the **'being' zone** only, the activities, such as health check and shopping service support, the services were point-to-point services or single user services and interactions. The second level, for instance in the **'belonging' zone** only, such as birthday parties, computer learning classes and phone calls to send thoughtful messages, were the services that involved more interaction, longer involvement and experience and mental exchange. The third level was the **'becoming' zone**, which included drama, talent shows and art exhibition of the elderly. These activities usually involved personal achievements and collaborative work and required more time. They built self-actualisation and contributions to society. From the perspective of the AEIOU framework, the analysis showed that the **'Being' activities were relatively simple, explicit and concrete**. They also involved fewer stakeholders. **'Belonging' and 'Becoming' involved more stakeholders, environments, interactions and objects**, leading to more **complex scenarios and abstract experiences**.

Summary of identified problems:

- **The concept mapping tool facilitated clustering:** The tool supported a holistic approach to research contexts and a review of project values from the point of view of project vision rather than activity-based exploration.
- **Perceptual mapping supported clustering activities by a group of participants, leading to effective early prototyping:** This could enable a mutual agreement on some abstract concepts, promoting more efficient prototype development.
- **Service design prototypes varied from simple and concrete experiences to complex and abstract experiences:** This phenomenon is common to social innovation projects and usually involves a **breakthrough at the system level**.

4.11.2 Project reflection

This case revealed three essential things. An effective prototyping process requires detailed and careful planning of the implementation of the concept brainstorming tool for a holistic perspective and framework. It is also important to note that an effective iteration design process requires a clear and systematic framework to support prototype development, particularly during the early stage prototyping process. Successful communication (mutual agreement and participation) between participants is also essential. Thus, a **strategic early prototyping framework** is needed.

Are ‘Being’ activities easier to visualise or prototype because of fewer factors and/or abstract features? Are ‘Becoming’ activities more complex and/or abstract that prototyping becomes more difficult? It would be worth investigating these observations.

4.12 Case XII: Elderly Service Design Workshop for Home Services Team

CASE XII
Review of a short workshop addressing specific services for the elderly in a conceptual framework

This case was an extension of the concept mapping exercise (3Bs model) for the formulation of initial concepts (early prototype stage) used in Case XI, which described all services for the elderly. This workshop examined the current situation of home services in terms of facilitating the quality of life of local seniors (service recipients) and the design of future services. The mapping exercise during the workshop provided important information as it focused on a specific part of the service component of a large NGO, which served more fragile elders who had difficulty receiving services at the centre. The case reviewed the concept mapping of targeted services instead of all types of services.

This workshop was offered to a team of social workers (around 20 staff) from an NGO called Hong Kong Christian Service (Kwun Tong Integrated Home Care Services team, Hong Kong) and providing home-based services to local seniors, such as food delivery, home cleaning, body maintenance, health check and demand for government benefits or other NGO benefits. I conducted a one-hour workshop in 2018 for this group of social workers, including the team's chief supervisor, the senior manager and the deputy director, responsible for the rehabilitation and community services offered to the elderly in the NGO.

The main difference with the tool used in Case XI was that the tool helped define 'Being', 'Belonging' and 'Becoming' and the coding system, which helped the participants brainstorm and cluster current and future activities as indoor or outdoor activities.

4.12.1 Identification issues and problems related to early phase prototyping

This workshop showcased how the 3Bs mapping tool could help map the complex service scenario of an organisation and offered a potential service design strategy or direction to the participants by indicating the distribution of current services. More importantly, it identified the areas of services that needed improvement. The senior manager of the NGO also mentioned that they found this tool useful as it could review their diverse services holistically (in terms of quality of life) and provide an overview of services at the level of the organisation with senior and junior staff. It was meaningful to the manager as this tool helped junior staff and other colleagues to connect their individual services to other services as a whole. Junior staff could use this overall picture to deliver stand-alone services/tasks in a holistic or organisational manner, instead of a narrow view of individual problems or concerns.

This case illustrated that a concept mapping tool (constructed according to the theory) could guide the workshop participants to formulate a clear and feasible **pre-prototyping strategy** (during early phase prototyping), leading to a more effective and concrete iterative prototyping process. As this workshop targeted social workers dedicated to home services, they brainstormed more innovative activities and interactions than Case XI. For instance, the concept of a 'community kitchen managed by the community members' comprehensively addressed the quality of life of the elderly. At the same time, the map immediately indicated the position of this new service to the participants compared with other current services. This was crucial for the management team.

Figure 4.12.1 Based on the map used in Case XI, this modified map illustrates the three conceptual values responding to the quality of life of the elderly, with a labelling system to facilitate clustering by the participants.

Figure 4.12.2 After mapping all current services and proposed future service concepts, I clarified some concepts with the social workers (participants) and asked about other possible concepts.

Summary of identified problems:

- **Concept mapping contributed to effective clustering in a holistic way in a theoretical framework:** As previously mentioned, the workshop tool was modified to help the social workers map current services and co-create new services. This 3Bs map supported the clustering of different concepts according to the theory of quality of life. This generated a meaningful and feasible prototyping strategy when the designers (or participants) were able to predict the value of the concept in a holistic picture.
- **An effective workshop tool should allow the participants to be confident:** Visualising complex mapping in a clear and relevant theoretical framework definitely encouraged the participants to have the confidence to move forward the prototyping process. For instance, this case examined how to improve current elderly home services (e.g. enhancing healthcare maintenance). Thus, the theoretical framework on quality of life (being, belonging and becoming) was relevant to the assessment of the services and to inspire future service design development.
- **The concept mapping tool as an analytical tool/process could enhance early prototyping:** Although the workshop was rather short and could not carry through the iterative prototyping process, senior management shared positive feedback on the function of the tool with a relevant theoretical framework. It enabled to review the value of a large number of service activities (including small-scale or stand-alone services) and new concepts following a logic (the three zones and overlapping areas). It allowed senior staff to make a better decision about the prototype's investment as long as they could ensure that the design was in line with their future development strategy (in a holistic picture of the centre, not the objective of an individual service session) or fulfilled a missing part of the whole plan.
- **The workshop participants with similar backgrounds and agendas needed more effective collaboration and communication:** All participants were social workers and coordinators who worked closely to serve the same group of seniors with similar needs (compared with those of the integrated service centre in Case XI). I observed that they supported each other (e.g. remind other colleagues if someone had forgotten a concept), shared concepts (e.g. discuss

new concepts effectively as they had the same background information and did not need to explain the context in detail) and agreed more effectively (e.g. they shared similar goals and agreed on some terms or concepts without a conflicting perspective).

4.12.2 Project reflection

This case played an important role in this research, as it was the only case formed by a whole group of participants from the same profession (with similar training and value) and a team serving a similar group of clients (comparatively more focused on the services/requirements they provided). Compared with other workshops with a variety of participants from diverse backgrounds, this case eliminated many factors. Thus, the workshop process was very smooth and the tool performed effectively. All participants learned new concepts through the mapping process and proposed new services they had never previously imagined or explored. They successfully developed a promising new service design at the prototyping stage because of its practicality. For instance, the participants were inspired by the mapping patterns and combined two existing services into a new service to improve the quality of life or reduce the concerns of service receivers (e.g. being + belonging). Therefore, from this perspective, we can assume that the participants can create new concepts if concept mapping is strategically organised to inspire new and innovative ideas.

4.13 Conclusion of the analysis of the 12 workshop cases

Based on the reflective notes on the processes of the 12 selected common cases (participatory design workshops with various group sizes and goals), the problems and opportunities affecting the early phase concept prototyping process were clustered and coded. **Thirty-seven issues** causing negative and positive effects on early phase concept prototyping were identified (Table 4.2). The coding scheme contained 15 concepts (Table 4.3), leading to the conclusion that **15 types of concepts** were related to the effective facilitation of early phase concept prototyping in participatory design workshops.

Table 4.2 Summary of the analysis of the 12 cases (in Chapter 4).

I	Co-creation Programme 2015 (Post-it and sketching as tools in the prototyping process)	• Lack of real representatives (or real users). • Knowledge in different contexts was needed. • Designer dominated. • Different levels of professional knowledge affected the level of participation of different non-professionals. • Concept generation and quick prototyping process were short.	-Workshop specific to the participants and the context. -Constraints induced by professional skills. -Constraints induced by unfamiliar knowledge. -Time limitation.
II	My Quality Home Living – The Elderly Creative Workshop (prototyping process driven by visual tools)	• Misalignment and misorientation: The participants had difficulty manipulating the furniture or product items accurately. • Visual information facilitated trial and error: Important for concept exploration and modification. • Visual representation helped articulate the user experience (intangible experience): Compared with a normal questionnaire with verbal clues, more accurate user perceptions of their needs were collected through graphical or visual representations, in particular the concepts related to the spatial relationship between users and objects, the goal being to create a user experience. • The participants did not have the exact or correct experience related to the research context.	-Problems of visual-spatial reasoning. -Advantages of the visual approach. -Constraints induced by unfamiliar knowledge.
III	Preferable Elderly Home Design	• Prototyping using predefined modelling materials enabled creative participation.	-Advantages of adopting

	Prototyping Approach (3D tool)	• Prototyping a familiar space/design enhanced reflection. • The prototyping process worked as an open research approach.	physical models in the research and design phases.
IV	Jockey Club Retreat Workshop	• The participants differed in their visual-spatial performance. • The participants explored the design iteratively.	-Advantages of the visual approach. - Advantages of adopting physical models in the research and design phases.
V	KODW 2017 Elderly Design Workshop by RCA	• User journey or scenario prototyping used for concept integration by a larger group of participants. • Scenario prototyping helped develop (i) concepts focused on problem identification, (ii) concepts focused on service solutions and (iii) concepts focused on product solutions. • Concepts with concrete actions. • Concepts with abstract directions.	-Advantages of the visual approach. -Aspects of concreteness. -Aspects of abstractness.
VI	The Park Lab 2017	• Most tools used in the workshop were text based. • Abstract concepts could not be easily imagined by inexperienced people. • Prototyping was a learning process for tackling abstract or unfamiliar experiences.	-Concept development process driven verbally. -Aspects of abstractness. -Prototyping as a research approach/design hypothesis.
VII	PolyU x HHCD Healthy Ageing in Hong Kong: Hong Kong Care Homes	• User research could not guarantee appropriate or creative insights. • No early prototype testing limited the possible solutions or creative concepts.	-Problems affecting prototyping. -Difficulty in implementing quick prototypes.
VIII	Intergenerational Game Design Workshop with and for the Elderly	• A clear framework led to earlier prototyping. • A range of prototyping activities, from a simple scenario (single person experience/single product system) to a complex scenario (collective experience of people/product-service system involving various levels of stakeholders).	-Preparation for the enhancement of early phase prototyping. -Prototyping as a research approach/design hypothesis.
IX	WeDesign Programme by JCDSI	• Incomplete participatory design approach. • The participants (students) lacked concrete and precise experience in furniture design and materials processing know-how. • There were obstacles to prototyping.	-The level of representation in the design process. -Constraints induced by

			unfamiliar knowledge.
X	Workshop for Community Service Platform Planning (Yi Pei Square)	• Lack of description of objects or services. • Lack of details about user experiences/interactions.	-Verbally driven concepts. -Problems affecting prototyping.
XI	Elderly Service Design Workshop for Integrated Services Team	• The concept mapping tool facilitated clustering. • Perceptual mapping supported clustering activities by a group of participants, leading to effective early prototyping. • Service design prototypes varied from simple and concrete experiences to complex and abstract experiences.	-Prototyping as a research approach/design hypothesis. -Advantages of the visual approach.
XII	Elderly Service Design Workshop for Home Services Team	• Concept mapping contributed to effective clustering in a holistic way in a theoretical framework. • An effective workshop tool should allow the participants to be confident. • The concept mapping tool as a tool for analysis and synthesis enhanced early prototyping. • The workshop participants with different backgrounds and agendas needed specific effective collaboration and communication.	-Advantages of adopting theory as the mapping logic. -Preparation for the enhancement of early phase prototyping. -Advantages of the visual approach.

Table 4.3 Coding scheme of the characteristics and problems of the early phase concept prototyping process.

[redacted]	
1) Workshop specific to the participants and the context	• Lack of real representatives (or real users) in the prototype process. • Different combinations of participants from different backgrounds affected the results of the workshop.
2) Constraints induced by professional skills	• Designer dominated. • Different levels of professional knowledge affected the level of participation of different non-professionals.
3) Constraints induced by unfamiliar knowledge	• Knowledge in different contexts was needed. • The participants did not have the exact or correct experience related to the research context. • The participants (students) lacked concrete and precise experience in furniture design and materials processing know-how. • It became an obstacle to prototyping.
4) Time limitation	• Concept generation and quick prototyping process were short.
5) Problems with visual-spatial reasoning	• Misalignment and misorientation: the participants had difficulty manipulating the furniture or product items accurately.
6) Visual approach for active and effective analytical and exploratory prototyping tasks	• Mapping visual and verbal concepts facilitated analytical and synthesis activities, in which trial and error could be carried out for concept exploration and modification.

	• Visual representation helped articulate the user experience (intangible experience). • Effective mapping tools enriched the participants' confidence. • The participants differed in visual-spatial performance. • User journey or scenario prototyping used for concept integration by a larger group of participants. • Scenario prototyping helped develop (i) concepts focused on problem identification, (ii) concepts focused on service solutions and (iii) concepts focused on product solutions. • The concept mapping tool facilitated clustering. • The theory-based concept mapping tool led to effective concept identification/clustering. • Perceptual mapping facilitated clustering activities by a group of participants, leading to effective early prototyping.
7) Advantages of adopting physical models in the research and design phases	• Prototyping using predefined modelling materials enabled creative participation. • Prototyping a familiar space/design enhanced reflection. • The prototyping process worked as an open research approach. • The participants explored the design iteratively.
8) Aspects of concreteness	• Concepts with concrete actions.
9) Aspects of abstractness	• Concepts with abstract directions. • Abstract concepts could not be easily imagined by inexperienced people.
10) Concept development process driven verbally	• Most tools used in the workshop were text-based approaches. • Lack of description of objects or services. • Lack of details about user experiences/interactions.
11) Prototyping as a research approach/design hypothesis	• Prototyping was a learning process for tackling abstract or unfamiliar experiences.
12) Problems/difficulties in the implementation of prototyping	• User research could not guarantee appropriate or creative insights. • No early prototype testing limited the possible solutions or creative concepts.
13) Preparation for the enhancement of early phase prototyping	• A clear framework led to earlier prototyping.
14) Prototyping as a research approach/design hypothesis	• A range of prototyping activities, from a simple scenario (single person experience/single product system) to a complex scenario (collective experience of people/product-service system involving various levels of stakeholders). • Service design prototypes varied from simple and concrete experiences to complex and abstract experiences.
15) Level of representation in the design process	• Incomplete participatory design approach.

Chapter 5 Prototype-ability

This chapter reviews the range of prototyping activities and identify prototyping issues when transforming verbal concepts into visual concepts from the perspective of dual coding theory.

5.1 Reflection on prototyping as a technique to facilitate collaborative learning and system thinking

Reflecting on the constructionist model of ‘learning-by-making’, prototyping (prototype making) as a product design and research approach has been recognised for its guarantee of developing innovative concepts in the individual or collaborative work environment. A prototype is usually used as a tool to support experiments or interventions and to evaluate the research goals. It also facilitates participatory design and user-centred design. However, prototyping involves both coded and tacit knowledge that design educators and practitioners find difficult to explain, especially for non-designers. This chapter summarises and discusses the characteristics of prototyping, including type, format and principle, through a literature review. Reflecting on the designers’ intentions and the dual coding cognitive learning process, I proposed a descriptive framework illustrating the dual actions experienced by designers, which enable to study the improvement of the prototyping process.

A prototype is a **simplification of a product concept** intended to **solve product development problems** (Otto & Wood, 2001). It can be considered as an ideation technique in which decision-making occurs when a physical object is built and encourages the generation of new ideas: **‘we build to think’** (Dam & Siang, 2019). Prototyping (prototype making) has been recognised for its effectiveness by both design and non-design practitioners as an essential step for innovation, collaboration and creativity in design (Hartmann et al., 2006). Described by Murray et al. (2010), prototyping is **the design of a working model of a product or service to test the reactions of potential clients and providers**. It is an **informal evaluation or testing approach** to generate an incomplete idea and move quickly to practice. The operating principles of prototyping include a fast process, low cost production, tangible experience, iterative design and feedback from users and specialists. Thus, the principle of **'fail earlier to succeed sooner'** followed by prototyping approach represents in the actual context of use of prototype (Burns et al., 2006; Brown & Wyatt, 2010).

Prototyping has become a buzzword since the introduction of the movement of design thinking, 3D printing and maker culture (Halverson & Sheridan, 2014) in the last decade. More people recognise that physical models help **transform** an **intangible concept or two-dimensional experience** into a **physical or three-dimensional object**, which can be better understood by its users, such as perceiving form factors or ergonomic responses (Dam & Siang, 2019). In Hong Kong, many non-academic organisations, such as the Hong Kong Design Centre, and some professional societies promote design thinking and offer participants a glimpse of the ways designers think or work. The main target audiences are non-design professionals, such as business community leaders and civil servants. The design thinking process of the Stanford d.school and the double diamond model of the British Design Council are the main guiding principles used to introduce prototyping, allowing many people to understand the importance of prototyping.

Hillgren et al. (2011) explained the benefits of incorporating prototyping as one of the methods for establishing **long-term engagement with stakeholders to develop social innovation projects**. It can be used to help participants **openly discuss, understand conflict, develop empathy, understand and respect the similarities and differences of others** through the visualisation and experience of collective creation before implementing it as a 'final' product, which conceptually limits subsequent interpretations, modifications and negotiations. In terms of bottom-up social innovation initiatives, the prototype also plays a **catalytic and binding role**, allowing all stakeholders, especially non-professionals, to **participate and build ownership**. As it allows for **collective involvement and iterative development**, prototyping not only supports conventional design processes, but also applies to the **social economy by forming coalitions**, for example by connecting users and professionals, and resolving conflicts, by reaching an agreement between stakeholders to establish personal interests (Murray et al., 2010). In recent years, social service providers in Hong Kong have also shown great interest in prototyping. For example, they have contacted design researchers and professionals to offer training and advice on the prototyping technique.

It is worth noting that most stakeholders perceive prototyping as a set of professional skills.

I discussed with other stakeholders, such as design workshop facilitators and participants, to define prototyping and how this skill can be transferred more effectively, in particular to address the time constraints of short workshops (from a few hours to a few days) on design thinking. It was not as simple as expected. Innovation training focusing on early prototyping, such as sketching, scenario design, mock-up or model making, is well accepted as an effective strategy for developing quality design concepts that fit the market. Unfortunately, I witnessed many cases of failure and difficulties in advancing effective prototyping practices with different workshop participants, in particular those without art or design training. To understand this problem, this chapter clearly defines prototyping and explains how its results can benefit pedagogical development in design schools and the promotion of design thinking in other disciplines.

5.1.1 Scope of prototyping methods

In design education, prototyping involves materials processing techniques (from hand tools to mass production methods), eye-hand coordination training (sketching and modelling) and visual-spatial thinking (using two and three-dimensional visualisation practices). It is a time-consuming investment. Prototyping is a relatively discipline-specific know-how and is therefore difficult to teach or implement in a short-term course. What are the factors that contribute to effective teaching of prototyping other than time? To answer this question, we must first understand in detail the prototyping experience.

Dam and Siang (2019) presented eight common prototyping methods (or types) in their overview of prototyping, although they indicated that there is an infinite number of ways to build a prototype. These common methods are the following:

1. **Sketches and diagrams** (e.g. a visualisation of concepts by doodles or hand sketches)

2. **Paper interfaces** (e.g. a draft of a paper-based mobile application interface design to help users give feedback on their experience)
3. **Storyboards** (e.g. a sketch of a storyline to explain the user's journey or experience)
4. **LEGO prototypes** (e.g. a set of modular toys or components to facilitate quick model making)
5. **Role play** (e.g. imitation of a scene or situation in which the potential user can gain experience and reflection)
6. **Physical models** (e.g. the three-dimensional mock-up of a chair design for ergonomic evaluation)
7. **Wizard of Oz prototypes** (e.g. functional demonstration of a partially finished automated machine triggered by people rather than a complete computer system)
8. **User-driven prototypes** (e.g. a prototype made by the user who can tell the researcher his/her real preferences or perceptions)

These methods can demonstrate tangible experiences, such as ergonomic or mechanical, and intangible experiences, such as aesthetic or symbolic, through low fidelity to high fidelity creations, ranging from early phase concept to functional manifestations. The forms of these eight prototyping methods are distinctive, but the interplay of their functions in the design process is confusing.

To further explain the problem, I differentiated these methods as illustrated in the matrix below (Figure 5.1). Based on the review of various designs or design research projects, prototyping methods have two main types of characteristics: the details of the context, between low and high fidelity, and the dimensions of the perceived user experience, for example from two-dimensional visual information to animation, including symbolic meaning and cultural practices. The overlapping characteristics of these methods may explain why identifying the best prototyping method during the design development process is challenging for both designers and non-designers. Novice designers may face uncertainty, which hinders the effectiveness of product development or design collaboration because of its ambiguity, and there is no absolute prototyping method. In contrast, experienced designers choose the most practical prototyping method, as appropriate. For instance, prototyping methods may depend on the accessibility or availability of relevant materials, tools and objects. Two of the prototyping types, ‘Wizard of Oz prototypes’, meaning stimulation through a fake function or set-up, and ‘user-driven prototypes’, which position the user as the prototype maker, are not included in this matrix, as they refer to the prototyping engagement strategy instead of the form of the work.

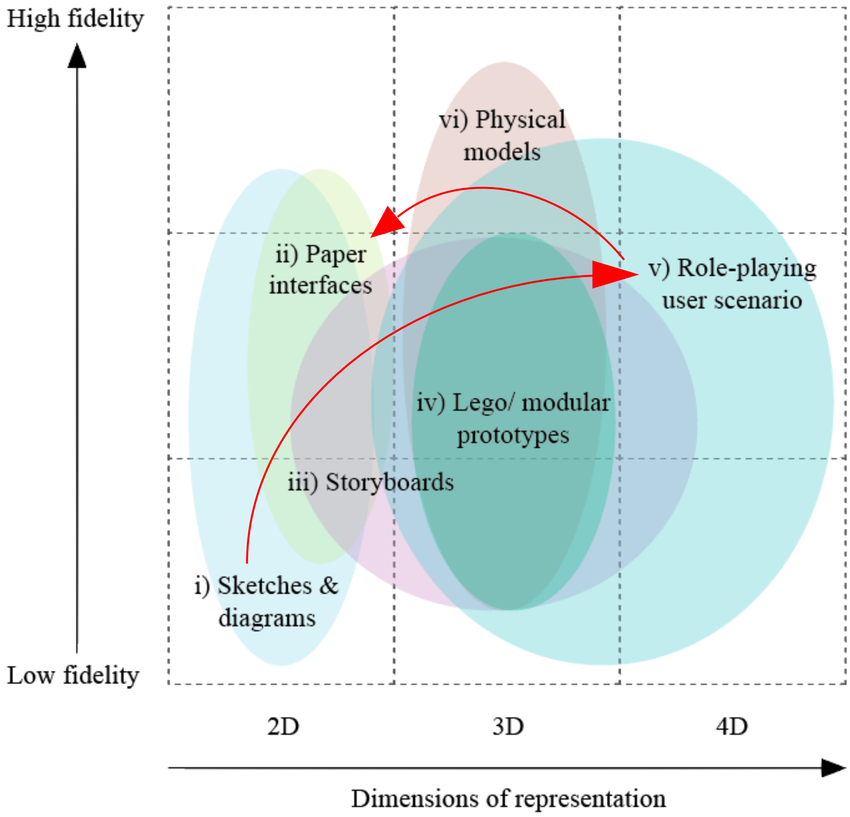


Figure 5.1 Matrix of prototyping methods illustrating the two main types of prototype characteristics. Designers may quickly visualise (or explore with mental images) the most appropriate or effective method based on the resources available during the prototype planning process. The paths of the red arrows illustrate the designers’ intention to identify the most reasonable type of prototype across different characteristics or levels of performance, based on the two dimensions. Source: Author.

5.1.2 Dual coding in the prototyping process

The application of the above matrix helps to support the prototyping process. For instance, as indicated by the red arrows, the spectrum suggests that designers can develop a concept from a sketch to a role play prototype at the representation dimension level and simultaneously address the concreteness or richness of the information provided by the prototype at the level of fidelity. During this process, designers make sense of the design concept through a dialogue between the verbal concept and the visual concept (a sketch or a prototype).

This sense-making mechanism can be understood by the dual coding theory described by Allan Paivio (1971, 1986). The theory explains the dynamic associative processes in the two cognitive actions (a subsystem of holistic sensory cognition) that connect verbal and visual stimuli and representations (Clark & Paivio, 1991). Stimuli include newly experienced materials through sensory systems (e.g. visual, auditory and kinaesthetic) and previously learnt materials stored in memory (knowledge). The theory is often used to support the learning experience of students by adopting verbal and visual means together and improves the memory and depth of the learning contexts. Paivio postulated that 'visual and verbal information is encoded and decoded by separate, specialized perceptual and cognitive channels in the brain'. The visual channel simultaneously manipulates mental images or non-verbal entities (also called imagens). Verbal entities, such as spoken or written words (also called logogens), operate linearly and sequentially in the language channel. When the same information is presented to the brain in different forms, for instance verbally (written notes of a design concept by the designer) and visually (sketch or model created by the designer), it is called 'dual coding' and the combined use of visual and textual information can increase comprehension. This helps explain why designers always use sketching or other visual means to carry out research and brainstorming in combination with verbal and/or different visual contexts, such as historical information, symbols and abstract verbal theories. Visual information can enhance the understanding, development and memory of verbal (abstract) information.

In design practice, this theory can explain why designers articulate verbal and visual codes or materials to develop purposive design artefacts, capable of better communicating with the public or users. While moving quickly between different actions, designers explore the most sensible prototyping approaches and think critically about the constraints of product form development. This process can take place simultaneously in the designer's mind, on paper and in the manual preparation of physical materials and tools. I argue that the immediate cognitive action of the prototyping process is the learning experience perceived by designers who perform design tasks while recognising and associating logogens (verbal stimuli) and imagens (visual stimuli). So, why are there many types of prototyping methods and why are several methods generally used in a design project? During the design process, designers articulate the possibilities of design (or appropriation) and justification (or reflection). Connections between logogens and imagens, called referential connections, refer to a mechanism that looks for references to link words with images or images with words. Movement between different pairs can be considered as the articulation process in which designers adopt different prototyping methods and carry out the iterative process. For instance, if a designer wants to explore an outdoor seating platform to enable intergenerational interactions between older and younger generations, at least the physical model (to examine seat height or ergonomics) and the storyboard method (e.g. demonstration of the sequences and pictures of the types of user experiences that may occur in a specific site or situation) should be applied to support the design hypothesis for further development.

In addition, it is necessary to further explain the implicit relationship between this cognitive movement (the back and forth between logogens and imagens) and the motivation of designers to shape and move forward the idea generation and prototyping process. The following discussion describes the situation through the distinction between science and design and the constructionist perspective on the designer's experience. If we aim to build a model to explain the cognitive experience of designers in the prototyping process mentioned above, we should explore the forces that drive designers to shape visual forms.

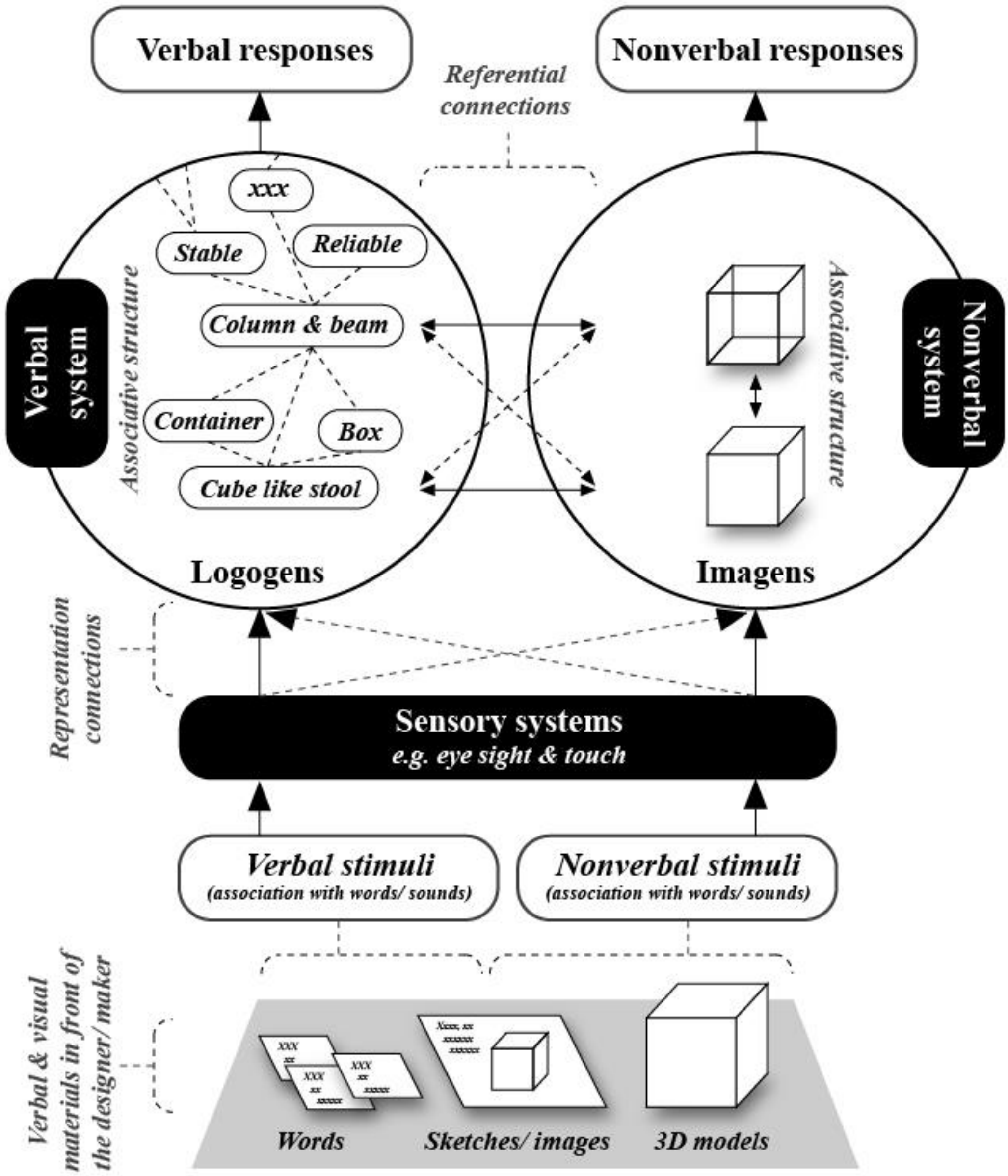


Figure 5.2 This diagram illustrates the mechanism of the dual coding theory proposed by Allan Paivio (modified from Paivio (1986)), indicating the coding action with two paths (the two cognitive subsystems), from the detection of verbal and visual materials to the associations and hierarchies of verbal entities and the part-whole relationship between mental images and non-verbal entities. Source: Author.

More importantly, in the prototyping process, designers perform sketching, scenario or other modelling activities. According to this dual coding mechanism, the dialogue space for **referential connections** between logogens and imagens is where the **prototype-ability** occurs. An articulated prototyping process should be able to enhance the mental activities of designers who identify, associate or transform **abstract concepts** and **concrete concepts**. This **prototype-ability** is the **factor** that affects the effective prototyping process. However, the way we can ensure efficient transformation, from abstract concepts to concrete concepts, is problematic when we look at **design tasks (AEIOU and sketching)**.

5.1.3 Dialogue connects analysis and synthesis

In product design practice, a prototype is not only a representation of an innovative concept, but it also plays a role as a catalyst to enhance understanding and enable communication at the personal level and collaborative level. One of the essential features of prototyping is that it interweaves creation and reflection (research) iteratively. Thus, prototyping or a prototype exists in different forms and its flexibility or diversity is the reason why those unfamiliar with prototyping cannot explicitly describe it or understand it correctly. Cross (2001, 2006), Rittel and Webber (1973), Simon (1969) and Alexander (1964) clarified the distinction between the characteristics of general design activities by differentiating between scientific/analytical perspective and design/synthesis perspective (Table 5.1). We can further implement these two distinctions to discuss the differences in prototyping processes: analytical prototyping and synthetic prototyping.

Table 5.1 Distinction between the characteristics of general design activities by differentiating between scientific/analytical perspective and design/synthesis perspective.

	Analytical	Constructive (Synthesis)	Stated by
Characteristics	Scientific and engineering problems are **'tame' problems**.	Design and planning problems are **'wicked' problems.**	Rittel and Webber (1973)
	Scientists try to **identify** the components of **existing structures**.	Designers try to **shape** the components of **new structures**.	Alexander (1964)
	Natural sciences examine **how things are**.	Design examines **how things should be**.	Simon (1969)

	The practice of science is **repeatable**.	The practice of design does not need to be repeatable and in most cases it must be **unique**.	Cross (2001)
	Designing is a **pattern recognition** process.	Designing is a **pattern synthesis** process.	Cross (2006)
Examples (visual means only)	The action of recognising or understanding the pattern or structure of the artefact through sketches or other visual means. The action of studying part or a specific component of the whole through visualisation. The action of clarifying the relationship between the design features and dimensions or confirming the measurements.	The action of synthesising the proposed pattern or hypothesis through visualisation or prototyping. The action of materialising an abstract concept into a concrete concept by creating a tangible shape or form. The action of exploring unique forms and facilitating evaluation.	

Analytical activity in science focuses on how things are, on solving scientific problems (also called 'tame problems') and on identifying the components of existing structures or products. Moreover, the result or practice should be repeatable. Analytical prototyping involves recognising or understanding the pattern or structure of the prototype through a sketch or other visual means. It focuses on studying part or a specific component of the whole through visualisation. It also helps clarify the relationship between design features and dimensions or confirm measurements.

Synthesis activity in design focuses on how things should be, on solving design problems (also called 'wicked problems') and on identifying the shape of the components of new structures. Design practice does not need to be repeatable and usually works as a unique solution. In synthetic prototyping, the approach emphasises the process of pattern synthesis or hypothesis development through visualisation (e.g. association or combination of visual images) or the construction of physical models. It focuses on the materialisation of abstract concepts into concrete concepts (e.g. from an abstract idea of 'a comfortable seat' to a concrete image of a chair with cushion) by creating tangible shapes or forms. It also enables the exploration of unique forms and facilitate design evaluation.

In accordance with Cross' concept of design, through prototyping, a designer proposes additions and modifications to the artificial world, including knowledge, skills and values using artificial synthesis techniques. Design knowledge is inherent to the artefacts of the artificial world and is acquired through three design-related activities: designing the artefacts, using the artefacts and manufacturing the artefacts. For instance, in using the artefacts, knowledge about forms and configurations is acquired by copying, reusing or changing aspects of existing artefacts. In manufacturing the artefacts, knowledge is gained through manufacturing and reflecting on the manufacturing process or through instructions. Prototyping (or designing through prototypes) is a process of knowledge acquisition, in which designers experience both making (e.g. shaping, pattern synthesis) and reflecting (e.g. analysis, pattern identification) while drawing or building models.

Design involves substantial learning experiences, which can also be understood from the perspective of Papert's constructionism (Ackermann, 2001): learning by making (making things in learning). Mabogunje et al. (2008, p. 3) discussed the product development process in the framework of Seymour Papert's constructionism, which stipulates that children actively construct and rearrange knowledge based on their own experience in the world. Papert further built on the constructivist theory by asserting that constructivist learning can be enhanced by engaging in the construction of external things. In addition, Papert developed his ideas and those of Piaget for adults. Mabogunje et al. further pointed out that Papert's constructionism is 'a way of making formal, abstract ideas and relationships more concrete, more visual, more tangible, more manipulative, and therefore more readily understandable' (2008, p. 3).

Thus, the action of making of designers, such as analytical prototyping (research-driven activity, such as analysis of product features or user evaluation) and synthetic prototyping (creative/design-driven activity, such as provoking new insights), is also a learning process. The analytical process and the synthesis process occur iteratively until the final prototype is developed. What aspect drives the back and forth between these two distinct cognitive processes? This can be better understood from the perspective of knowledge creation.

Urging design to define its position in knowledge creation, the discussion of the differences between design (synthesis) and research (analytical) activities has emerged more formally and explicitly since the 2010s. Stappers and Giaccardi (2017) summarised various thoughts on this subject: the design activity usually involves the production of a creative work that is specific and concrete or situated. The research activity involves the production of knowledge that is generalisable and abstract. From the perspective of design research in academia and industry, they cited Liz Sanders' identification (2005) of the similarities and differences between the traditional design research approach, called information-based design research, such as usability testing and ethnography, and the designerly approach to study, called inspiration-based design research, such as cultural analysis and generative techniques. Similar concepts include the goal of creating something new (prospective perspective) while relying on known matters (retrospective perspective). This explains why different prototyping methods and intentional perspectives of designers are needed. These implicit and complex processes contribute to the learning experience of designers, design researchers and other co-workers to develop new concepts.

Making is an effective learning approach in constructionism (Halverson & Sheridan, 2014). The making process and knowledge production of researchers by physically making something can be understood as building blocks, from abstract to concrete and concrete to abstract (Ackermann, 2012), between delving into the wicked problem space full of various uncertainties and producing a concrete experience or prototype that demonstrates distinct yet tangible and intangible design functions, features or experiences.

From the review of different prototyping cases (as shown in the paragraphs below), I identified two implicit actions in which the designers operate prototyping activities (sketching or modelling) back and forth in two distinct zones in an iterative way. At one end, there is **retrospective action**, namely reproduction or crafting to duplicate (imitate, review, measure, correlate) the same or similar archetype and immediately develop hypothetical artefacts for analytical purposes. At the other end, there is

prospective action, namely the production of innovative or hypothetical artefacts that can be evaluated in the retrospective zone to prove the assumption or theory from the perspective of synthesis. Analytical-synthetic actions in the two zones are strongly connected. The representations can be 2D, 3D and/or 4D works (e.g. sketching, building physical model or animation). Prospective action is a high-level cognitive activity that aligns with the concept of **constructive forethought** proposed by Sutton and Williams (2010). They cited Gregory's (1987) statement that 'design generally implies the action of intentional intelligence'. Thus, this **sense-making intention** drives the momentum of cognitive changes from one side of the retrospective and analytical actions to the other of the prospective and synthesis actions. At the same time, designers develop the concept and prototype back and forth, from the abstract world (product of the analytical process, such as a verbal concept or a partial feature of a prototype (part)) to the concrete world (product of the synthesis process, such as a tangible model or the overall features of a prototype (whole)). These two momentums are illustrated in Figure 5.3.

Usually, the cognitive experience of designers shifts between analytical and synthesis modes (as indicated in Figure 5.3 – moves to the left when the designer processes the analytical/retrospective concerns and to the right for the synthesis/prospective concerns). This can operate as a dialogue between the designer and the artefact (intrapersonal level) or in the group discussion or the collaborative working environment (interpersonal level). It is perceived by designers as an iterative process during the development of a prototype, from abstract and uncertain concepts to concrete concepts.

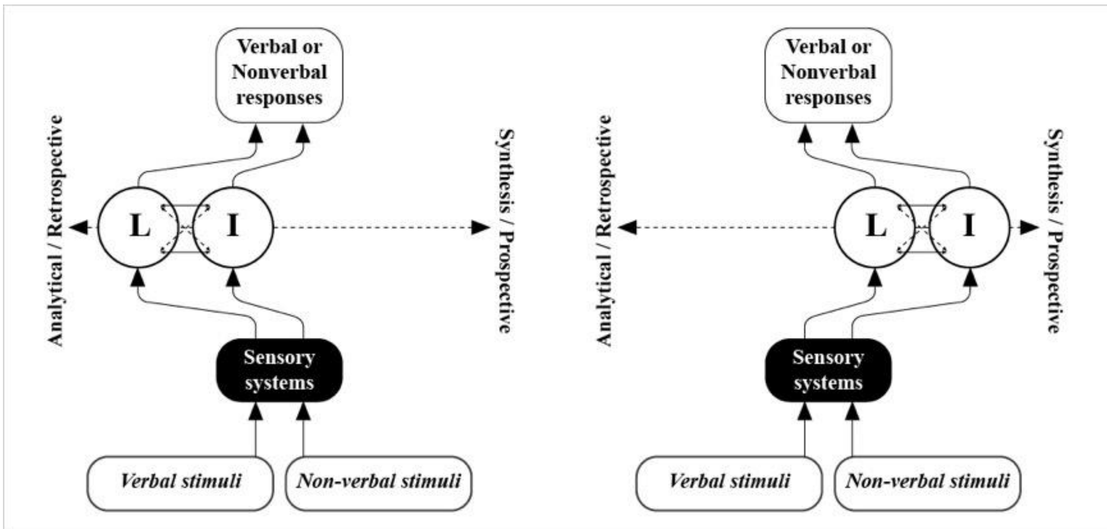


Figure 5.3 Diagram of the oscillation between analytical/retrospective actions and synthesis/prospective actions. It illustrates the vertical dimension of the prototyping process (the vertical path indicating the dual coding system, from the sensory stimulus to the designer's responses) and the horizontal dimension with the two ends (the horizontal path showing the intent of the designer who either operates analytical prototyping (retrospectively) or synthetic prototyping (prospectively). Source: Author.

For example, a group of designers (or participants) explore new user concepts for an outdoor park and the concept of 'intergenerational interaction' is given as the project theme. There are different possible responses. Someone may write the word 'intergenerational interaction', 'play', 'interaction' or 'fun' on paper. Someone may draw a place where an older person and his/her grandchild can play chess or a senior and a child running in the park and experiencing the landscape together. From the perspective of the workshop facilitator, s/he is concerned about how the designers select the best or most appropriate concept that can meet the objectives of the project, including active ageing and the satisfaction of the different stakeholders (and users). The designers will read the verbal or non-verbal stimulus and **interchangeably or forcefully connect or associate the concepts**, based on the process of oscillating actions from both ends (analytical/retrospective and synthesis/prospective). In practice, there are abstract and concrete verbal and non-verbal concepts, which appear with different **degrees of concreteness**.

5.2 Framework for the product prototyping process

Understanding the initial stage of the prototyping process is useful for connecting the prototyping method and its potential outcomes. In the beginning, designers should have specific design criteria, either verbal and/or visual concepts, before starting the early prototyping stage, whether they are clear or uncertain. Designers begin the prototyping process by having a goal, whether clear or not, that can be a concept in words and/or visual form. They attempt to comprehensively map different possible factors and elements, from partial consideration to holistic consideration. The mapping is based on two main considerations: product form development constraints and prototyping formats. Moreover, conceptual clarity itself is a relative concept and one of the main intentions of the designers. It will be further articulated during the materialisation stage. If designers have no concrete concept or image in mind, they can explore the concepts by doodling or scribbling, a stage before prototyping. Thus, prototyping only occurs when designers are ready to plan the fabrication or have already envisioned a potential concept in the form of a mental image, a sketch or a physical artefact.

To understand the relationships between actions, conditions and considerations, the diagram below illustrates (Figure 5.4) the cognitive processes of the designers, while perceiving verbal and visual stimuli during the early prototyping stage with the dual coding system as the first action (vertical movement). When logogens (L) and imagens (I) connect (or pair up), the second action (horizontal momentum) occurs at the level of two distinct mindsets/processes – the analytical/retrospective processes driven by the six constraints of product form development (intentions or questions of the designers regarding the substantiation of the product prototype) and the synthesis/prospective processes driven by the five principles of prototyping strategies and the eight appropriate prototyping formats. To initiate the dual action mechanism, one of the three common conditions of product form development intervenes. Finally, the prototype or test is the deliverable and can induce an iterative development.

Knowing the requirements and constraints (appropriate types and formats of prototypes) of product form development cannot explain the motivation of the designers when looking for possible methods. The driving force for selecting the appropriate prototyping method also requires the availability of the maker's resources and whether it is actionable or not. Camburn et al. (2015) proposed five design-oriented and actionable principles to help designers achieve the objective of a project. The following five principles are incorporated into the prototyping process in which designers can comprehend the final prototyping strategies. They refer to the appropriateness of the actions that designers can apply. This works as a supplement to the eight prototyping methods and six constraint considerations.

1. Hack commercial products.
2. Use basic crafting.
3. Prepare fabrication blueprints.
4. Repeat fabrication processes.
5. Include structural voids.

I developed a framework describing the mechanism for explaining the considerations of the designer's experience in selecting a prototyping approach and developing a prototype driven by the proposed dual actions – the vertical force being the dual coding path and the horizontal force the bipolar intentions of the designers shifting back and forth between the processes of analysis and synthesis. The processes involved iterative considerations of constraints and opportunities through different prototype methods.

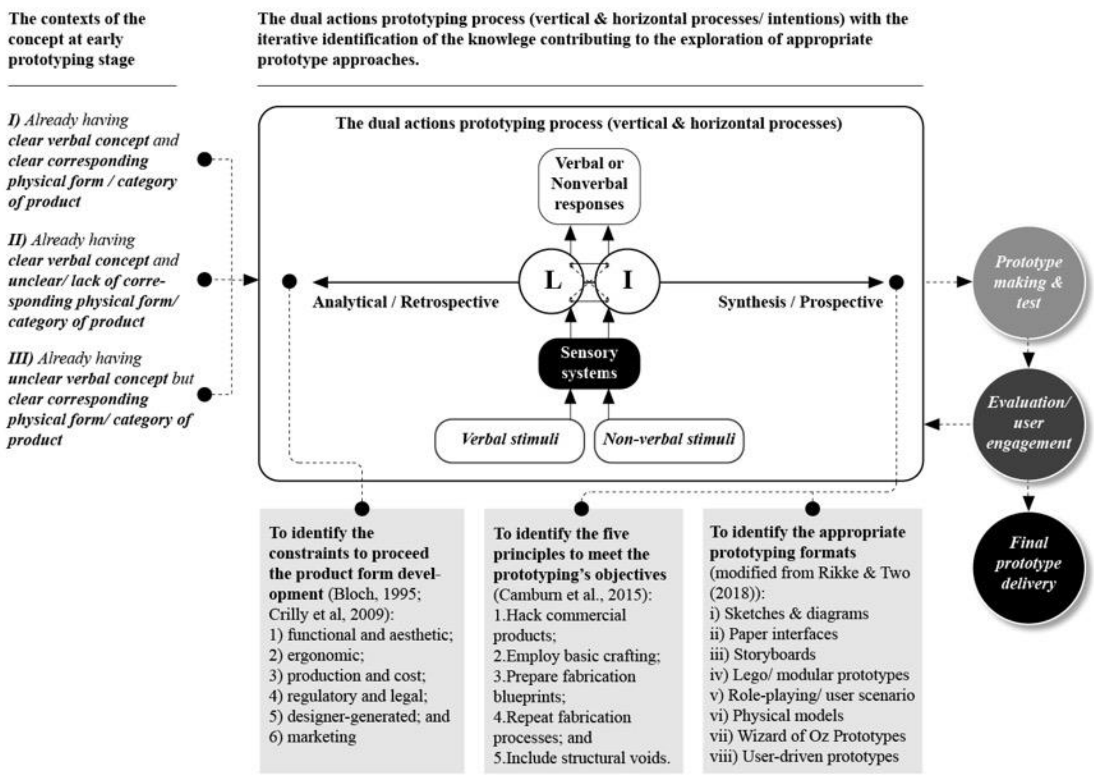


Figure 5.4 The dual action prototyping process framework. This shows how the constraints and opportunities of product form development and the different prototyping objectives and formats are connected and driven by dual actions. Source: Author.

5.2.1 Prototyping is a learning process in both retrospective and prospective zones

From the perspective of learning by making, I identified several characteristics of prototyping to further support the proposed prototyping process framework (Figure 5.4) through the development of five first-hand cases. Sketching or 'sketch-prototyping' reflected the importance of the cognitive back-and-forth between the analytical/retrospective zone and synthesis/prospective zone during the prototyping process.

As mentioned earlier, designers may conduct analytical activities to imitate, review, measure and correlate concepts through prototyping (e.g. sketching or modelling) in the retrospective zone. The first case focused on indigenous handicrafts and sought prototyping and design thinking solutions to support revitalisation. A sketch-prototype (Figure 5.5) was selected for discussion. It is a common practice to doodle or sketch to explore new ideas. However, sketching to facilitate learning (or enhance memory) plays a vital role in design, such as solving complex design problems. This sketch helped me build a mental model by mentally describing the relationship between the different components of the wooden cart and the fabrication method. This example showed that design researchers can adopt sketching as a method of investigating the form of an artefact (it can be done directly through visual or physical examination) and reverse engineering the fabrication process (indirect learning, which is a dry run in the mind) at a much lower risk or less investment in resources. To this end, the visual and spatial representation skills of design researchers were required. The constraints of form development (Bloch, 1995, in Crilly et al., 2009), such as functional, aesthetic and production considerations, were reviewed.

A sketch provides visual contexts (accompanied with verbal descriptions) to enhance the evaluation of the product experience for the development of a prototype, as both sketching and modelling can enable visual thinking, which allows to remember and manipulate visual images. This explains why sketching became a common tool used during the early concept development process and other phases. Sketching as a type of prototyping allows not only to envision the hypothetical design, but can also be applied to the analysis of artefacts or scenarios in which design researchers can explore the context in detail through visual means.

Visual contexts usually refer to the affective responses that the users can experience in human-product interactions, in which the stimulation of the users' senses can be triggered by the prototyping process or interactions with the prototype. A recognised framework to elicit the experiential effect of new designs is the three components or levels of product experiences proposed by Desmet and Hekkert (2007). As defined by Hekkert (2006, p. 160), product experience is 'the entire set of effects that is elicited by the interaction between a user and a product, including the degree to which all our senses are gratified (Level I: aesthetic experience – visual aesthetics, and tactile and kinaesthetic), the meanings we attach to the product (Level II: experience of meaning – semantic interpretation, symbolic association, linguistic expressions, and figurative expressions) and the feelings and emotions that are elicited (Level III: emotional experience – personal evaluation (appraisal) of an event or situation with beneficial or harmful impact)'. In practice, designers and researchers can use this framework to explain the phenomenon of (and guide) the iterative processes when evaluating the three types of product experiences induced by the visual concept while sketching or making the prototype.

Compared with written concepts, sketching (or prototyping) can provide visual information to the creators (or interpreters) who can not only associate the aesthetic experience (e.g. the representation of product forms and categories) and the experience of meaning (e.g. the semantic concept), but also the tacit or intangible product experience that verbal tools cannot support. For instance, the aesthetic experience (e.g. line quality) of a sketch can help the creators experience the abstract concepts of a sketch/prototype, such as soft/gentle or hard/robust characteristics of a design. Creators can also perceive additional information (such as emotional experience) while crafting or fabricating an artefact and material, induced by touching the material or associating the visual quality of the sketch/prototype. Furthermore, people can understand the implicit know-how while sketching or prototyping, such as creating a physical design or simply drawing on paper. This experience involves visual and spatial relationships that correlate with various design components, which cannot be easily communicated in words. These are some of the reasons why sketching or drawing is a popular method of collecting people's perceptions or expressing their individual understanding on certain points.

However, if the oral articulation of a participant or informant is an issue, for instance interviewing people who are deficient in verbal communication or who use a language other than their mother tongue, verbal thinking and verbal expression (e.g. written concepts on Post-it notes during design thinking workshops) are less successful compared with a 'sketch-prototype'. Conversely, building a physical model to create a direct copy of an existing design can also help builders or makers learn the unique structure and production method, which cannot be explicitly and comprehensively described through verbal descriptions alone.

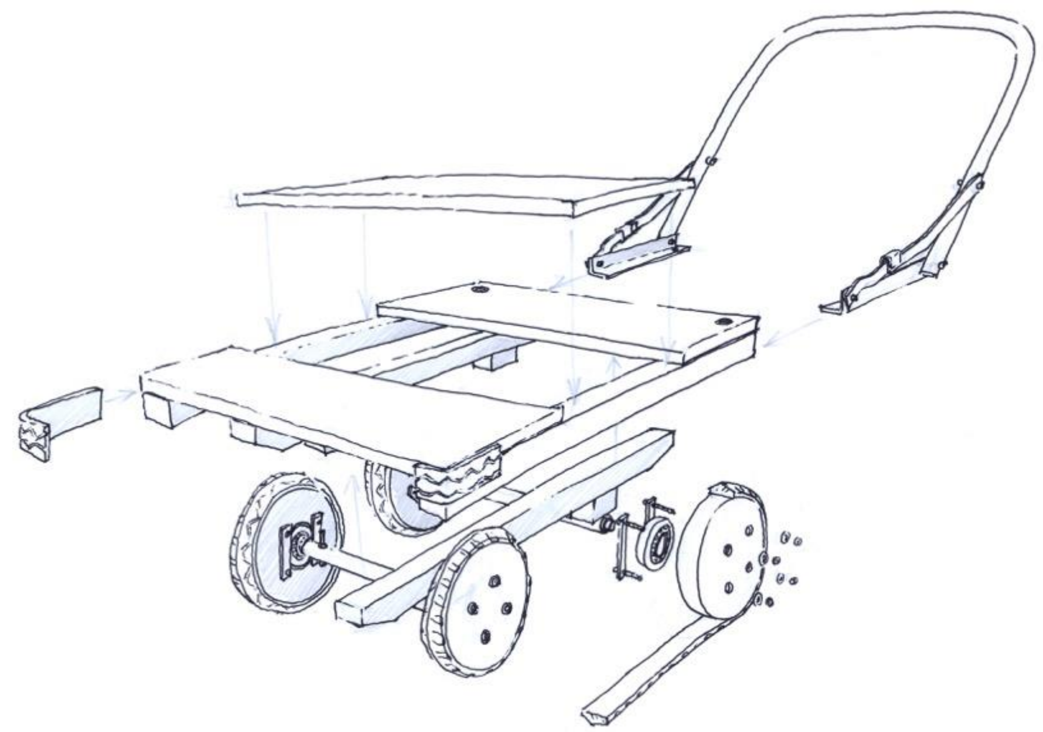


Figure 5.5 Sketch as a visualisation tool to investigate craftsmanship techniques, including the logic of the structural form, material selection criteria and fabrication methods. Drawing also helps visual communication between researchers, designers and producers (or craftsmen). Source: Author.

Case two showed how prototyping works as a synthesis process in a prospective manner. In this case, I produced an ergonomic chair design with adjustable backrest. Before exploring a new backrest, I examined several backrest designs of different ergonomic chairs through desk research and sketching. Using a quick paper mock-up (Figure 5.6) helped visualise the three-dimensional structure and mechanical movement that could not be quickly evaluated and shared with sketching alone.

Figure 5.6 The paper model shows the relationship between the moving parts of the design hypothesis. The animated structural feature of the design facilitated simulation and evaluation through sequential movement and tactile experience. Source: Author.

Practical work and the manipulation of tools can also help examine the design hypothesis, such as the identification of new design patterns. Case three was another example of the back-and-forth between retrospective learning and prospective learning. The project was an upcycled lampshade design and production project that a project team and I organised for a group of secondary school students. The students learnt the properties and opportunities of PET bottles by exploring their physical patterns and structural performance by cutting, bending and punching the material. They experienced and identified the characteristics of the material during the making process. After identifying a potential module or unit, the student reorganised (integrated) the components or units into a bigger piece of meaningful structure or pattern that functioned as a lampshade (Figure 5.7).

Figure 5.7 Searching design patterns or meaningful visual structures is one of the important learning experience and creative outcome of prototyping. This image presents the result of a group of secondary school students after they explored the material properties of PET bottles by trial and error and explored pattern recognition by organising the material in an exploratory manner. Source: Author.

Case four illustrated a fully functional prototype (Figure 5.8). The revamp of an old tram for the event called DETOUR 2013 funded by CreateHK provided the opportunity to develop a full-scale, functioning design prototype. The project created an alternative urban experience by transforming a street tram and the project team proposed a transparent envelope to emphasise the open concept and allow people to visualise and understand the internal structure of daily transportation design. We studied how the tram windows worked, how the linkage system helped open and close the windows and the traditional wooden structures of the tram framework, which became the primary concept and feature. Transforming the tram to become fully transparent was the experimental goal of the prototype. This working prototype not only generated a new transportation experience to real users, but also demonstrated an innovative yet feasible approach to the management of the tram company and the Electrical and Mechanical Services Department of Hong Kong that supported this new attempt and assumed the risks of the project. As mentioned above (Murray et al., 2010), prototypes help build coalitions between stakeholders and this case may also influence policymaking in the future. This example showed how a functional prototype can benefit from meaningful evaluation at the community level. Synthesis is essential in the prototyping process, but evaluation (or facilitation of analysis), such as supporting public engagement, could in this case be a more important goal of the project.

Figure 5.8 A tram with a transparent envelope that operated in Hong Kong Island and served people for more than a week at the end of 2013. LED lighting was used to highlight the internal mechanism of the tram. Source: Author.

The final case was a qualitative research project to understand the perceptions of seniors of home furniture and spatial needs by making a scaled-down model (Figure 5.9). My team developed the model to facilitate participatory design activity to engage elderly residents. The preparation of the model, including the selection, measurement and making of the apartment and furniture, provided background information and encouraged reflection by the project team. Assuming that the retrospective learning process was essential to the success of prospective prototyping, a new two-step prototyping approach was implemented in this project, based on the perspective that the participants/users were 'expert[s] of [their] experience' (Sanders & Stappers, 2008). The team visited the homes of the local elders who were instructed to build their current home furniture layout. The team asked about relevant living problems (retrospective questions), such as 'Does the bed meet your current needs?'. Then, prospective questions were asked (e.g. 'How about your needs in the future?'). The elderly designed and built their preferred home furniture layout and shared with the team the reasons for the changes (or lack thereof) to the design. This example showed that a modular prototyping tool can engage non-professionals to express their creative ideas and needs in a more accurate and accessible manner than with a questionnaire alone. It also helped the designer collect more real user needs by interacting with the informants and the prototypes. In particular, the participants were considered experts in their lives (expected to know their current home and personal needs well). Thus, prototyping with a two-step approach was more effective than one round of prototyping.

Figure 5.9 Participatory design activity conducted during a home visit to a local elder who was asked to design through a prototype his preferred home furniture layout with the modular components and models. The researcher recorded his thoughts through the think aloud method. Source: Author.

5.3 Conclusion

The above integrations of various theories and concepts aimed to map the overall cognitive experience of designers in the product design prototyping process. The main cognitive activity was the recognition of verbal and visual stimuli, in which analytical, constructive and creative associations between verbal and visual materials could lead to comprehensive learning and the development of new meaning or knowledge. It is illustrated as the vertical axis in the diagram of Figure 5.4 and represents the first dimension of cognitive action.

The five design-oriented and actionable principles, the six constraints of product form development and the eight prototyping formats are the main elements that guide the prototyping process. Designers operate all of these factors in the second dimension between two distinct zones – analytical/retrospective and synthesis/prospective actions on the horizontal axis. The description of this dual action prototyping process framework and the correlated cognitive learning activities are expected to promote future studies on improving prototyping strategies and pedagogy in design education.

Chapter 6 Concept representation from verbal to visual means

The discussion of the case study in Chapter Four suggests several important cognitive problems that can contribute to the enhancement of workshop design. The discussion in Chapter Five suggests that the representation of concepts (both verbal and non-verbal) based on the degree of abstractness and concreteness can affect prototyping activities in participatory design workshops. In addition, the questions of the implicit experience of the designers in the creation process cannot be answered directly from interviews. In this chapter, a design task was used to investigate how abstractness/concreteness (e.g. imageability of the verbal concept) correlates with the early phase prototype-ability.

Furthermore, the discussion presents the aggregated results of the informants from all disciplines and their corresponding average scores on visual and verbal thinking preferences, the concept generation performance of the scenario design (the AEIOU framework) and the relationship between the abstractness and concreteness of the verbal and non-verbal concepts. Content analysis was carried out with 58 informants and coding schemes were proposed. The relationship between the informants' concept brainstorming and prototyping performance was described qualitatively by coding the specific characteristics of the prototype-ability, with an emphasis on **'interactiveness'**, **'objectness'** and **'situatedness'**.

6.1 Preliminary study of the prototyping activities

6.1.1 Redirecting part of the research focus

After careful consideration of how participants generate verbal concepts and based on a review of the literature on imageability in verbs, I realised that people's visual-spatial reasoning skills may not be the only problem affecting the conceptual representation from verbal concepts to visual concepts or early phase prototypes. Indeed, the way in which people who are aware and able to interrupt their mental concept in verbs may also play a critical role. Thus, I revised the strategy of the design task based on the pretest to further focus on this particular cognitive process in the final round of user performance testing through an updated design task.

This chapter presents the analysis of the results of this design task implemented in a design thinking training workshop for people enrolled in the Good Seed 2018 Programme funded by the Social Innovation and Entrepreneurship Development Fund to nurture a start-up project with a social mission. This programme supports the innovative solutions of the younger generation to help disadvantaged people in Hong Kong, such as the elderly, people with disabilities, newcomers, ethnic minorities and the homeless. The participants were prepared to challenge complex problems or systems. Therefore, they were relevant to undertake this design task, which required the exploration and integration of multiple factors.

To carry out a more relevant task for a larger group of informants, I planned a preliminary design task for a smaller group of participants to analyse and evaluate the questions and the task design. Two main tasks were developed under the theme ‘intergenerational harmony park’ – concept brainstorming based on the AEIUO framework and scenario prototyping/sketching of the bench design to promote intergenerational harmony in a small park. The tasks included a consent form, a self-evaluation form, a questionnaire, an idea brainstorming sheet (user-product-environment), an AEIOU idea generation tool and scenario visualisation. AEIOU was adopted because it is commonly used in daily training and is easy to follow if a product (object) is one of the main outcomes. The following sections describe the analysis and discuss the results.

6.1.2 The trial

Ten people were recruited to participate in the preliminary version of the design task. This study was essential to finalise the design task activity. Ten samples were completed by undergraduates and graduates from different disciplines. The topic of the task, the time allotted to complete the exercises and the format of the task sheets were relevant and effective for the collection of appropriate and sufficient information for analysis. The samples are shown below.

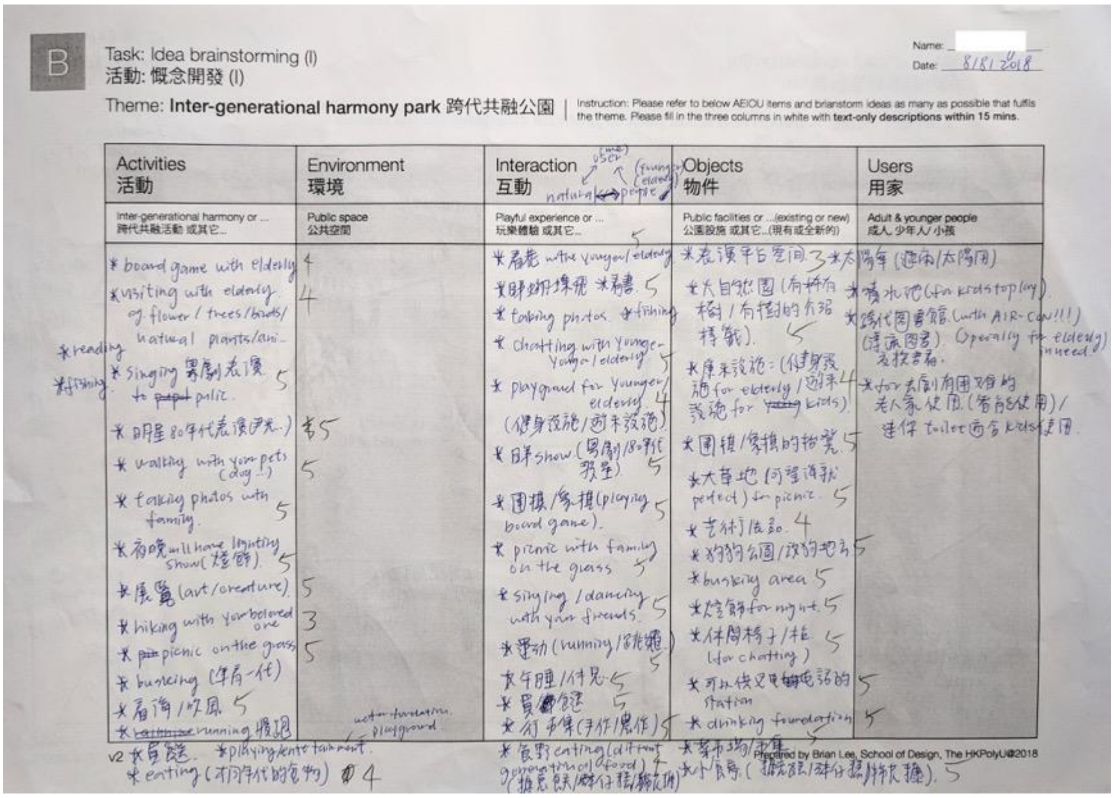


Figure 6.1 This is Sample 01 of the preliminary design task, one of the best samples in terms of generating the largest number of AEIOU items in 15 minutes.

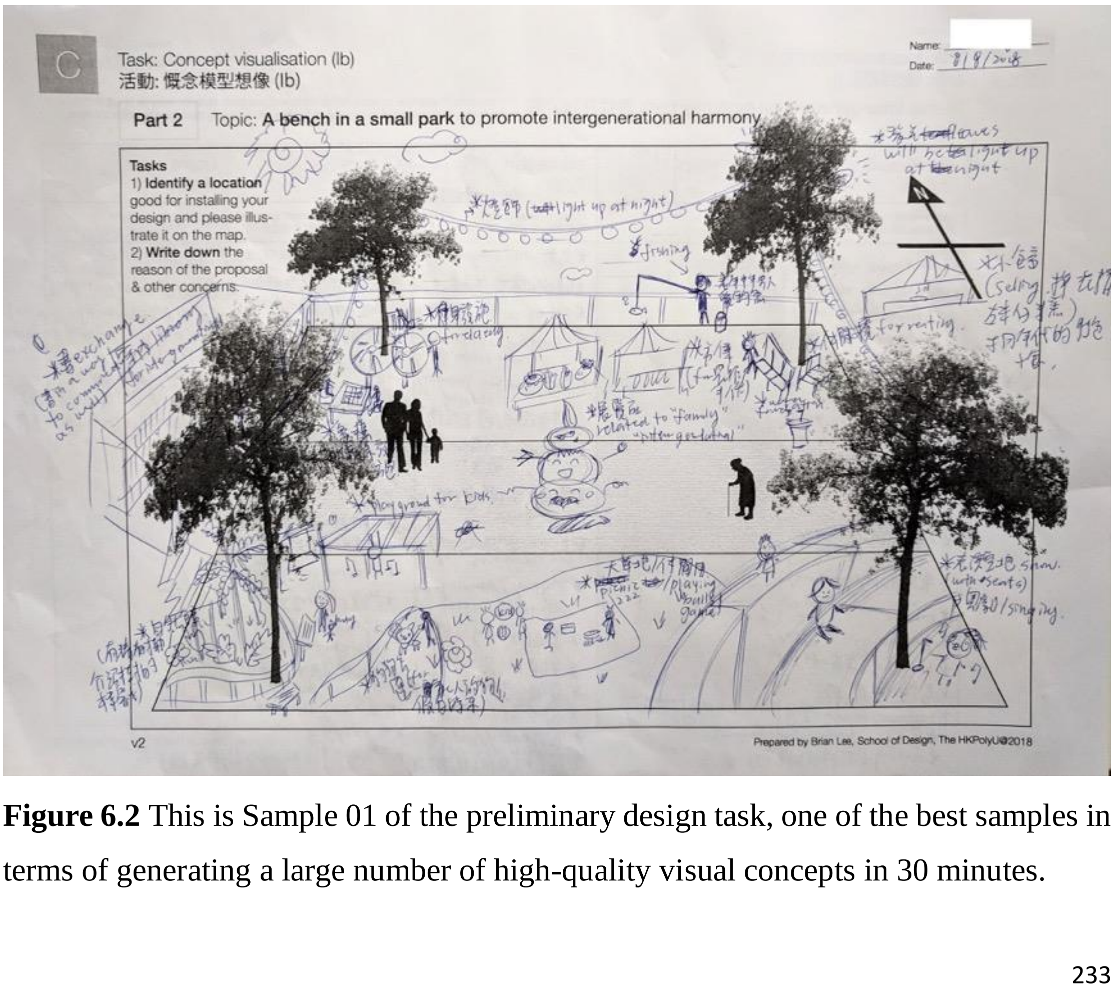


Figure 6.2 This is Sample 01 of the preliminary design task, one of the best samples in terms of generating a large number of high-quality visual concepts in 30 minutes.

6.2 Correlation with disciplines and performance in concept prototyping

After evaluating the task test, final versions of the design task sheets were generated for a design workshop with more than 60 people. To sensitise the participants and encourage them to immerse themselves and develop a productive and creative mindset, I implemented two quick exercises with a simple framework to warm up, especially for those who were not studying or working in art and design disciplines.

I approached the organiser of the Good Seed Programme and was accepted to offer the design task during the design thinking workshop. The recruitment criteria included current undergraduate or postgraduate students and graduates from a local higher education institution with Hong Kong citizenship. It was also assumed that the applicants were interested in at least one of the following social innovation themes: low-income families, elderly with limited resources, people with disabilities, new migrants, the homeless and other underprivileged communities. This ensured that the participants of this workshop had or were interested in knowledge and contexts related to social innovation projects. In the end, 60 participants registered for the workshop via an online recruitment system. They attended the design thinking workshop and completed the design task that I facilitated on 4 October 2018. Fifty-eight samples with valid data were collected.

6.2.1 Profile studies (age range and disciplines)

The participants were diverse enough to represent many major disciplines: fine arts, design, social sciences, healthcare, business, law and engineering.

General profile of the participants

Sixty workshop participants submitted their questionnaire, of which **58** were valid. The majority of the participants were between 21 to 25 years old (53%). The second (15-20) and third (26-30) largest age groups accounted for 30% of the sample. In other words, 85% of the participants were in the younger generation (from 15-30) and most were studying for a Bachelor's degree.

Table 6.1 Distribution of the participants' academic background and age in tabular form.

Education Background	Number of Discipline Classification	15-20	21-25	26-30	31-35	36-40	41-50
Art, Design and Media	11	1	6	2	1	1	
Arts and Humanities	1	1					
Business	12	1	5	3	1		1
Engineering	4		1	2		1	
Geomatics and Surveying	3	1	2				
IT and Computer Science	10		9				1
Law	3	1		1	1		
Medical Healthcare	3	2			1		
Social Science	6		4	1		1	
Unspecified	5	1	4				
Total	**58**	**8**	**31**	**9**	**4**	**3**	**2**

Age range	**15-20**	**21-25**	**26-30**	**31-35**	**36-40**	**41-50**
Age distribution of all participants	**8**	**31**	**9**	**4**	**3**	**2**

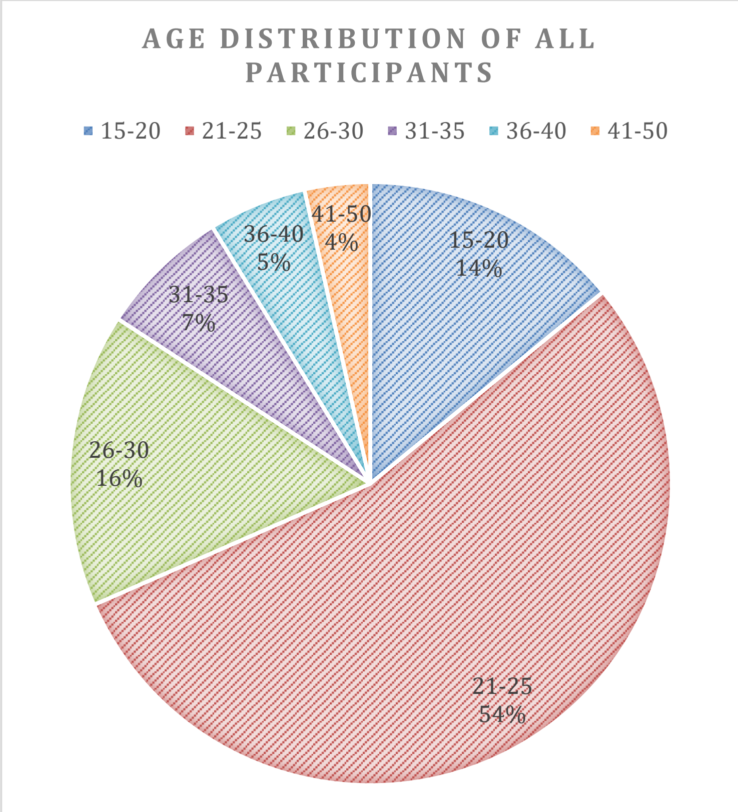


Figure 6.3 Age distribution of all participants in a pie chart format.

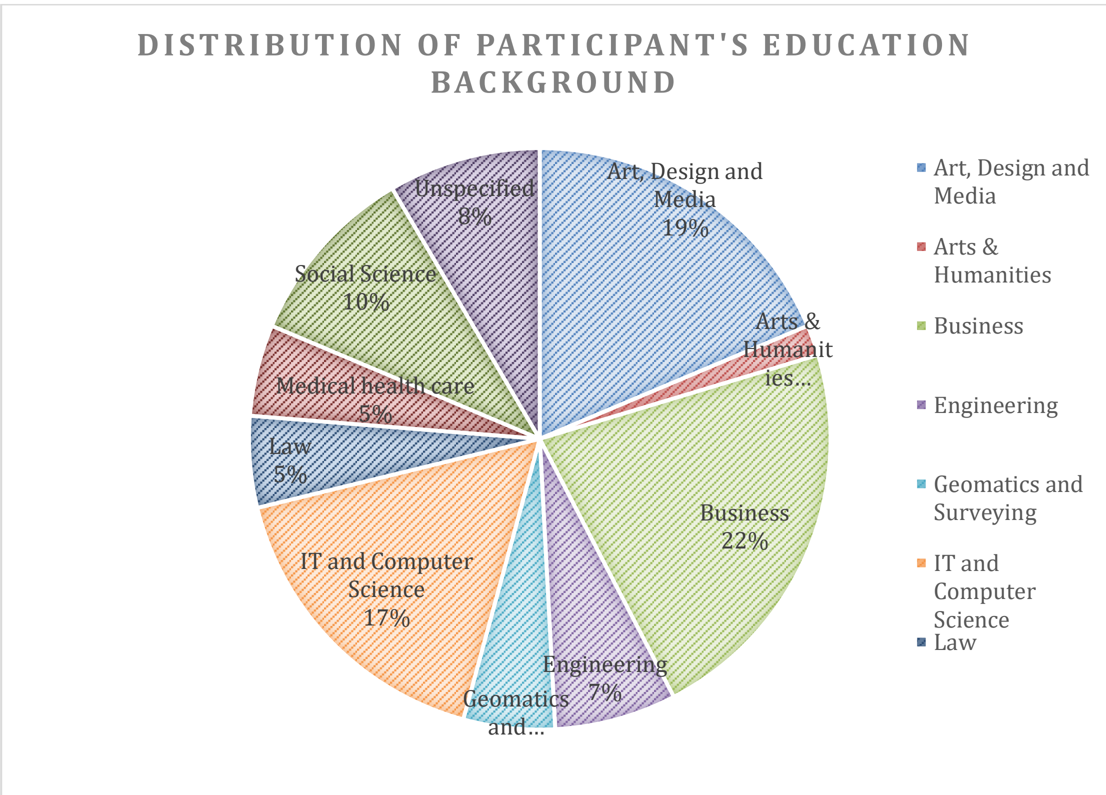


Figure 6.4 Distribution of the education background of all participants in a pie chart format.

Distribution of disciplines

The three main groups, comprising 58% of the 58 participants, studied ‘business’ (22%), ‘art, design and media’ (19%) and ‘IT and computer science’ (17%). The fourth, fifth and sixth groups were ‘social science’ (10%), ‘unspecified’ (8%), and ‘engineering’ (7%). The other groups were ‘medical healthcare’ (5%), ‘geomatics and surveying’ (5%), ‘law’ (5%), and ‘arts and humanities’ (2%).

6.3 Content analysis of the 58 participants’ performance

Fifty-eight participants took part in the design task of proposing a bench design for a small park to facilitate intergenerational harmony. After the coding process, each participant’s design outcomes were assessed based on their articulation of the verbal description of the brainstorming task according to the three main elements (activities, interactions and objects) and the scenario sketches that represented the selected design concepts to promote user interaction to experience intergenerational harmony. The assessment focused on three parameters: the level of detail, clarity and appropriateness of the outcomes.

Four main groups of concepts were identified and classified (Table 6.2).

Table 6.2 Overview of the coding table with the assessment and coding results of the 58 workshop participants.

[illegible]

6.3.1 Coding schemes of AEIOU results (first level)

Few observations were obtained at the beginning of the coding at the first level of concept clustering based on the AEIOU exercise carried out by the participants. The workshop facilitator expected to collect a variety of AEIOU concepts from the participants in terms of quantity and quality. Usually, people choose verbal language to express concepts, although drawing is allowed. With regard to outcome assessment (AEIOU concepts), obtaining more and diverse types of activities indicates a more successful case in terms of high performance in brainstorming ability. In addition, more detailed and accurate descriptions demonstrate that better communication can be achieved.

The first round of coding results focused on the **quality of the brainstorming process of the AEIOU concepts**. Eight coding schemes were identified in terms of the quality of AEIOU, including the identification or evidence of (i) the **tendency or proportion** of use of the verbal and visual means, (ii) the **concreteness** of the AEIOU concepts, (iii) the meaningful **relationship** between AEIOU elements, verbal language and visual language, (iv) the number of **transformation of** the AEIOU concepts into visual concepts (scenarios), (v) the **sensitivity** to choose verbal concepts, and (vi) the amount of **information about the user experience** (see Table 6.3).

Table 6.3 Eight coding schemes for concept generation based on the AEIOU framework.

AEIOU Concepts – Brainstorming Results							
Verbal means dominated/ verbally driven	AEIOU concepts work well with the sketch	Low concrete-ness of AEIOU (e.g. abstract interaction)	AEIOU not strongly connected to the sketch	No connection between verbal and visual concepts	Very few AEIOU are transferred to visual concepts	Sensitive verbal concepts on the topic	Lack of information about the user experience (e.g. seating, playing)
12	2	32	8	10	1	2	5

Three aspects summarised the reflection of the coding activities.

1) Variety of AEIOU concepts

In the study, most AEIOU and sketch concepts were similar. The main problem was that the wording used was abstract and no detail was provided. The limited duration of the exercise was a major factor affecting the results (lack of variety of AEIOU concepts).

2) Variety of scenario sketches

Like the AEIOU concepts, the sketches were similar. However, some participants produced more creative sketches that could not be derived from the verbal concepts.

3) Creativity

Most of the concepts were neither creative nor detailed. Short working time could be the main reason. Each exercise lasted 15 minutes. The dedication of the participants was also a major factor that was difficult to ensure. The entire workshop lasted about three hours, including a one-hour lecture and two hours of short and sequential tasks.

6.3.2 Coding themes (second level) – 'Objectness', 'interactiveness' and 'situatedness'

Further clustering was carried out to identify specific problems or concerns related to the ability to improve the early phase prototyping process. After examining the 58 samples, three main themes were identified: **'objectness', 'interactiveness'** and **'situatedness'**. These three key concepts contributed to the understanding of the prototype-ability. The characteristics of these three concepts are discussed below.

Table 6.4 Coding schemes (objectness, interactiveness, situatedness) highlighting the three perspectives of effective early phase prototyping.

Sketch / objectness							Interactiveness		Situatedness
Visual means dominant/ visual driven	Good sketch with detailed considerations	Good sketch but not connect to the theme	Very weak scenario sketch (cannot communicate)	Sketching is better than verbal	Rate high visual but weak in sketching	Sketching stimulates new concept or detailed thoughts	Weak 'interaction' concept	Interaction' is essential to overall design	Situatedness' contributes the critical part
	1					1			
			1						
			1					1	
									1
			1		1			1	
1	1							1	
1	1					1			
1	1								
			1						

(i) **Categories in the sketches for 'objectness'**

The first group of concepts focused on the appropriateness and richness of the perceived value (properties/ level/ sensitivity/ articulation/ detail) of the **physicality of the visualised tangible concepts and descriptions** (called 'objectness' in this thesis) such as physical form, size, material, color, surface finishing, and functional features of the objects. As a result, seven categories were identified (see Table 6.5).

Table 6.5 Coding for the quality of the sketches addressing the aspect of 'objectness'.

Sketch – Objectness						
Visual means dominated/visually driven	Good sketch with detailed considerations	Good sketch but not connected to the theme	Very weak scenario sketch (cannot communicate)	The sketch is better than the verbal concept	Visually high but weak in sketching	The sketch stimulates new concepts or detailed thoughts
11	5	1	27	2	1	9

Total fifty-six coded concepts related to 'objectness' were observed. In addition, visual language contributed to 'objectness'. From the analysis of the informants' AEIOU exercises and sketches of the proposed prototype (in sketch form), one crucial element was missing, which seriously affected the representation of concept (scenario) prototyping. For instance, Case N33 indicated some form factors (written in blue) – bench height, extended board to support tea drinking activity and chess games, curved shape allowing the users to sit and enjoy a performance in front of them and the seating layout for different orientations. These were related to the physical performance of the bench.

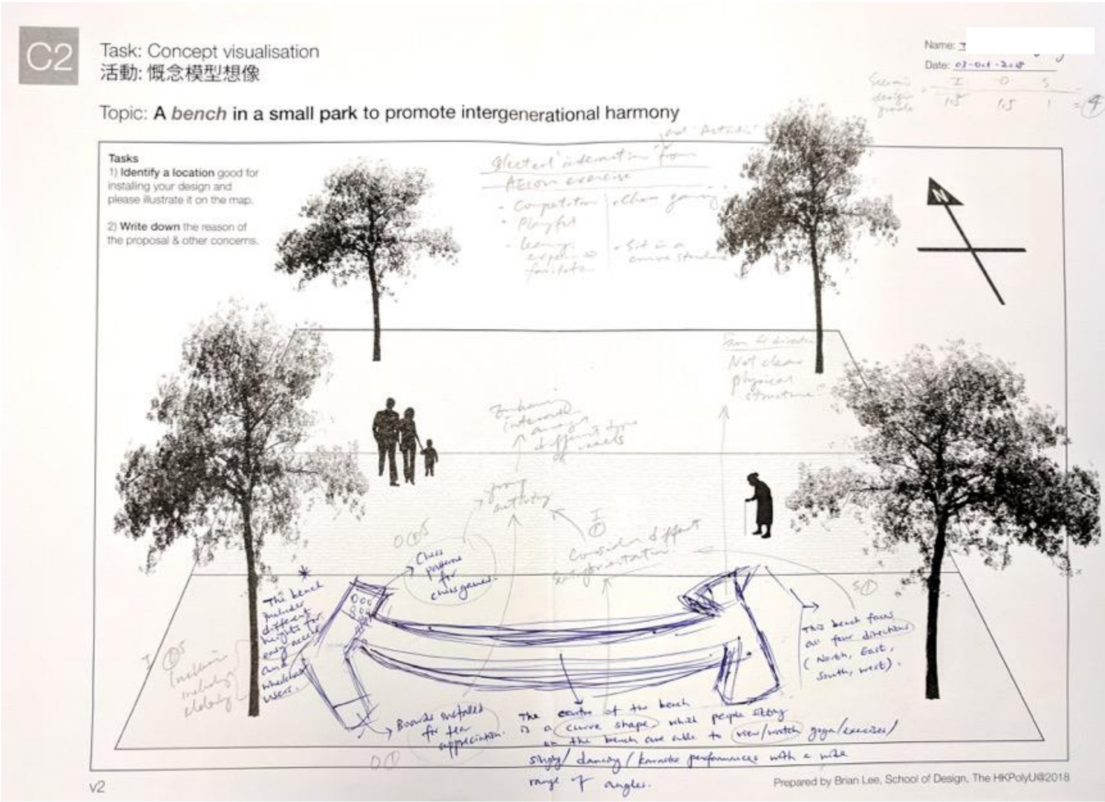


Figure 6.5 Case N33. The participant illustrated a T-shaped bench to provide a variety of services.

(ii) Categories in the sketches for 'interactiveness'

The second group of concepts focused on the appropriateness and richness of the **interactions amongst user-object-environment** (called 'interactiveness' in the thesis) represented by the sketches and descriptions such as sharing of joyful experience, knowledge transfer, dialogue building and collaborative work etc. Two categories were identified (see Table 6.6).

Table 6.6 Coding for the performance of the sketches addressing the aspect of 'interactiveness'.

Sketch – Interactiveness	
Weak 'interaction' concept	'Interaction' is essential to the design
9	7

Comparing to the wide varieties of concepts raised in the category of 'objectness', The amount of concepts of 'interactiveness' were lacking. Total sixteen coded concepts of 'objectness' were mentioned (21% of out of total seventy six concepts generated by all participants) in this category were observed.

(iii) Categories in the sketches for 'situatedness'

The third group of concepts is about the concept on the appropriateness and richness of the **environmental factors and spatial qualities** (called 'situatedness' in the thesis) represented by the sketches and descriptions such as the details about the types of the landscape, location, trees or other natural elements, climate of the region, and spatial characteristics etc. Substantial descriptions are better to support the participants to define the environmental related opportunities and constraints which can enable more explicit and in-depth engagement on concept prototyping. One category is identified (see table 6.7).

Table 6.7 Coding for the performance of the sketches addressing the aspect of 'situatedness'.

Sketch – Situatedness
'Situatedness' is an essential element
4

It is worth to note that the concerns or awareness of environmental or spatial qualities were very limited. Only four mentions (around 5% of coded concepts on 'situatedness' out of the total seventy six concepts generated by all participants) in this category were observed. This result informs that the majority of designers or workshop participants are lack of awareness and exploration of the situational factors even though they had carried out the AEIOU brainstorming exercise where the ‘environment’ is one of the five components of the project elements.

6.3.3 Concreteness issue that contributes to ‘interactiveness’, ‘objectness’ and ‘situatedness’

It was clear that the informants (designers or participants of the test) were unable to extensively imagine or visualise the concepts to address the ‘objectness’ and ‘situatedness’. On the other hand, the informants performed better in ‘interactiveness’ but it is verbal language driven. This phenomenon aligns with the observations I made from the selected workshop’s cases. People heavily relies on verbal means which are abstract and information to support prototyping is very limited. I argue that appropriate, rich and sophisticated explorations in ‘objectness’ and ‘situatedness’ contributes to the formation or transformation of a feasible concrete concept for tangible prototyping from abstract concept. Workshop time is the constraint. However, I suggest that the workshop planner and facilitator need to develop method and tools to enable participants to express and explore abstract and concrete concepts without language barrier. IOS model is one of the method to enhance the collaboration experience and result for effective tangible prototyping. I can be integrated into the process of AEIOU or POEMS exercise.

In conclusion, I proposed **a three descriptors** (interactiveness (I), objectness (O) and situatedness (S)) **enabling model which could** facilitate the designers (participants) develop **higher prototype-ability concepts** during the early phase concept generation process, as workshop instructions or as a method to enhance workshop facilitation. I argued that this clear descriptive framework could generate comprehensive scenario/product/service design concepts with both verbal and non-verbal descriptions, which could easily be transformed into tangible experiences/physical prototypes in the next stage of the design process. Meanwhile, the IOS enabling model can be used to assess the quality of the early phase product design concept.

6.4 Comparing discipline-specific performance in concept generation

To better understand how the performance of the participants, in particular **the relationship between verbal concepts and visual concepts, could lead to more effective prototyping, three IOS key descriptors/ indicators** were adopted to provide information through a correlational study of the assessment of previously evaluated design thinking workshop (the creative works by a total of 58 informants). The **first indicator** was the participants' self-evaluation of their overall **thinking styles or preferences** (visual, verbal, mathematical, musical and kinesthetic). The sum of the five styles of individual participants was counted. Each informant rated his/her own thinking style or preferences on a five-point scale to indicate the five dimensions of intellectual-ability.

The mean scores of the 58 samples in 'art, design and media', 'business', 'engineering', 'geomatics and surveying', 'IT and computer science', 'law', 'medical healthcare', 'social science' and 'unspecified' were 16.14, 17, 14.5, 18.88, 12.83, 18, 15.15, 12.75, 14.67, 15.17, and 14.6, respectively.

The **second indicator** was the average score of all participants on their performance in the **AEIOU brainstorming task**. A single category of concept was considered '1' item. The larger the number of items, the higher the score. The mean scores of the 58 samples in 'art, design and media', 'business', 'engineering', 'geomatics and surveying', 'IT and computer science', 'law', 'medical healthcare', 'social science' and 'unspecified' were 18.45, 23, 13.38, 16, 14, 0 (no data), 10.9, 23.5, 6, 15 and 21, respectively. Two samples (N33 and N2) of which generating twenty seven and six AEIOU items respectively are shown at below (figure 6.6 and 6.7).

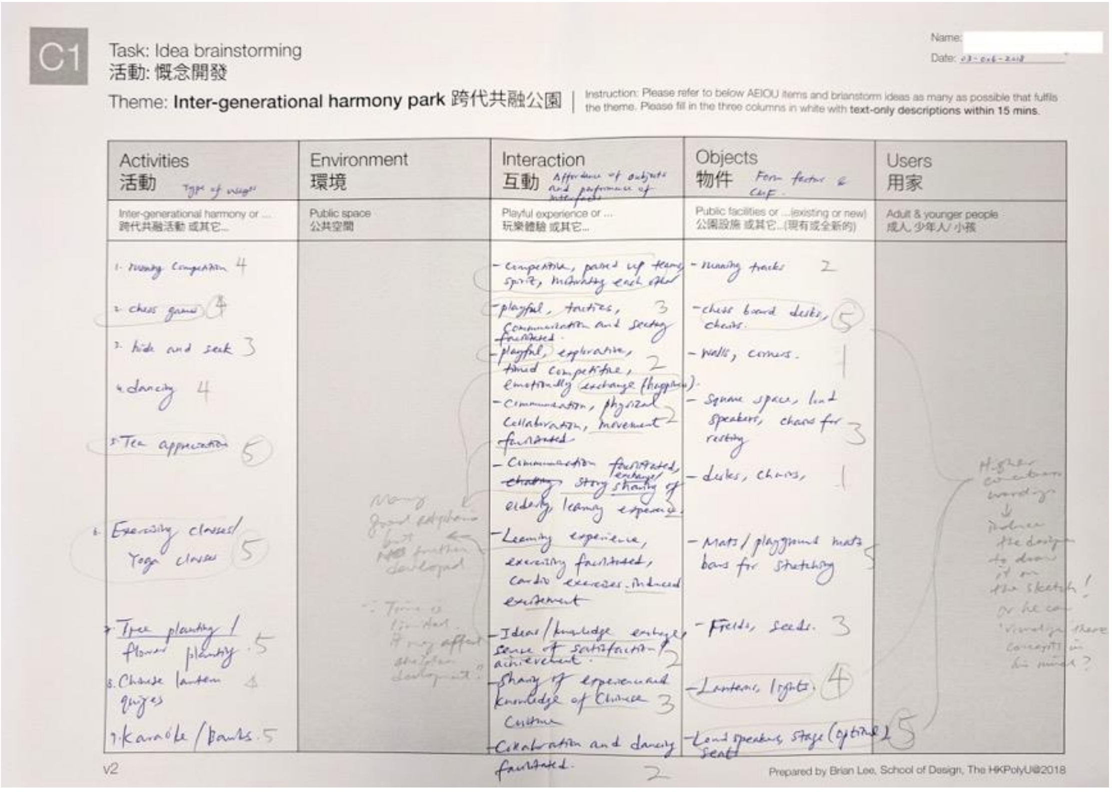
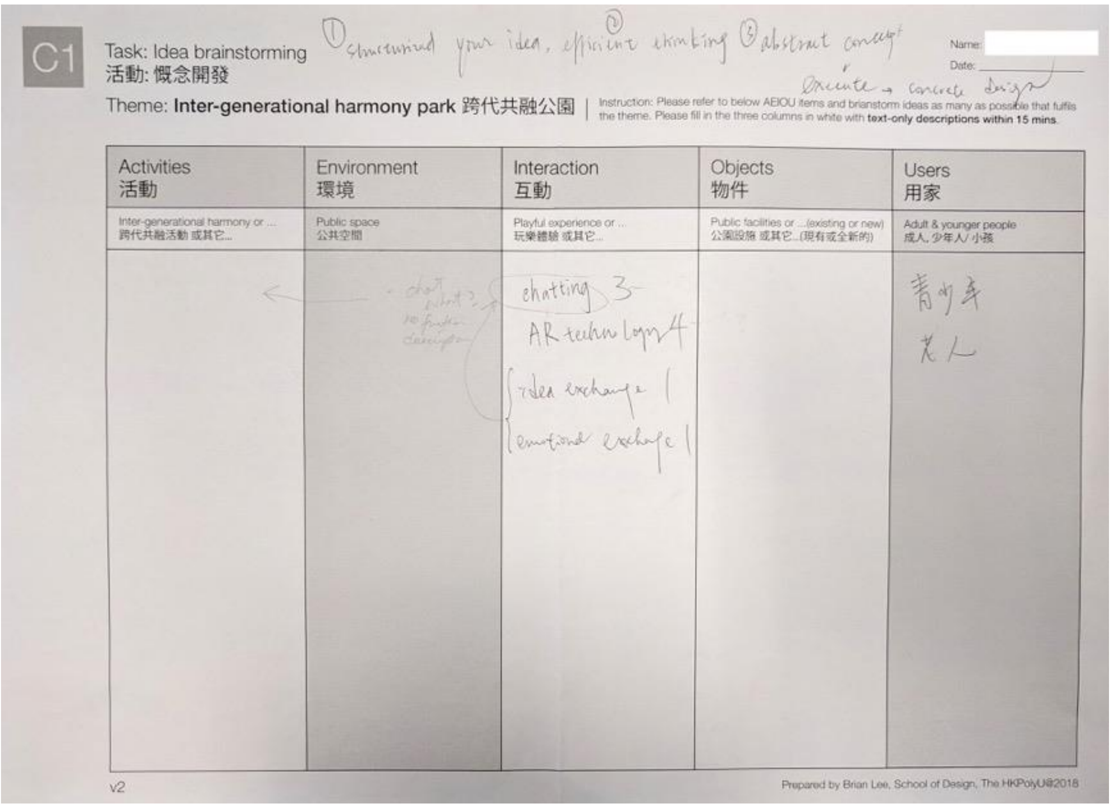


Figure 6.6 This is Sample N33, one of the top five samples that generated the largest number of AEIOU items in 15 minutes. Twenty seven items were produced. The notes on the evaluation of the concreteness of individual concepts and comments are written in pencil.



C1 Task: Idea brainstorming
活動: 概念開發

① structured your idea, ② efficient thinking ③ abstract concept → execute → concrete design

Name:
Date:

Theme: **Inter-generational harmony park** 跨代共融公園 | Instruction: Please refer to below AEIOU items and brainstorm ideas as many as possible that fulfils the theme. Please fill in the three columns in white with **text-only descriptions within 15 mins.**

Activities 活動	Environment 環境	Interaction 互動	Objects 物件	Users 用家
Inter-generational harmony or ... 跨代共融活動 或其它...	Public space 公共空間	Playful experience or ... 玩樂體驗 或其它...	Public facilities or ...(existing or new) 公園設施 或其它...(現有或全新的)	Adult & younger people 成人, 少年人/ 小孩
		chatting 3 AR technology 4 idea exchange 1 emotional exchange 1		青少年 老人

v2

Prepared by Brian Lee, School of Design, The HKPolyU©2018

Figure 6.7 This is Sample N2, one of the bottom five samples that generated the smallest number of AEIOU items in 15 minutes. Six items were produced. In addition, the participant incorrectly wrote the ‘activities’ items in the ‘interaction’ column.

The **third indicator** was the average score of all participants on their performance in the **scenario design task**. According to the content analysis based on the evaluation of the abstractness, concreteness and imageability of the participants’ outputs (AEIOU and scenario design concepts), an individual performance score on the effectiveness of the representation of the final design concept based on the **three coding themes (interactiveness, objectness, situatedness (IOS))** was proposed as the parameter to measure the outcomes. The mean scores of the 58 samples in ‘art, design and media’, ‘business’, ‘engineering’, ‘geomatics and surveying’, ‘IT and computer science’, ‘law’, ‘medical healthcare’, ‘social science’ and ‘unspecified’ were 18.45, 23, 13.38, 16, 14, 0 (no data), 10.9, 23.5, 6, 15 and 21, respectively.

Figure 6.8 illustrated the comparison of the top five disciplines with the highest number of participants and their average performance scores for (i) self-assessment of individual thinking preferences; (ii) AEIOU brainstorming (the higher the score, the greater the number of items generated); and (iii) ‘interactiveness’, ‘objectness’ and ‘situatedness’ (IOS) evaluation. It is worth to note that participants who perceived higher thinking ability (intelligence profiles) didn’t perform better in AEIUO exercise as well as IOS score. For instance, participants in engineering group showed highest self-assessment score but their performance in both the AEIOU and IOS assessment were not outstanding. Social science group rated themselves quite low in self-assessment on their thinking abilities. However, they performed the best at IOS assessment. The expression of verbal language in the assessments of AEIOU and IOS are very essential. Sketching ability comes next. Disciplines not strong in verbal and visual languages may induce **less motivation to the engagement of the workshop process**. In other words, disciplines strong in verbal and visual language (in particular verbal language) can **dominant** the creative process in collaborative work. Participants who are weak in verbal language, such as lower educational level or not using mother language, their voices may not reflect in the co-creation process. Thus, the workshop facilitator should provide varieties methods for the expressions of personal concepts of individuals.

Few participants performed exceptionally. For instance, the participants from ‘law’ (three people) and ‘art & humanities’ (one people) are the group with less people. They both reached the highest AEIOU score (figure 6.9).

Besides, this evaluation focused on the mean scores of each disciplines. The result cannot prove that the background of education is the absolute factor to the performance of creativity and quality (in AEIOU and IOS exercises). For instance, although the IT group received very low AEIOU and IOS scores, one participant with IT background who is the fifth highest performance in AEIOU exercise and reached an IOS score above the mean of all participants.

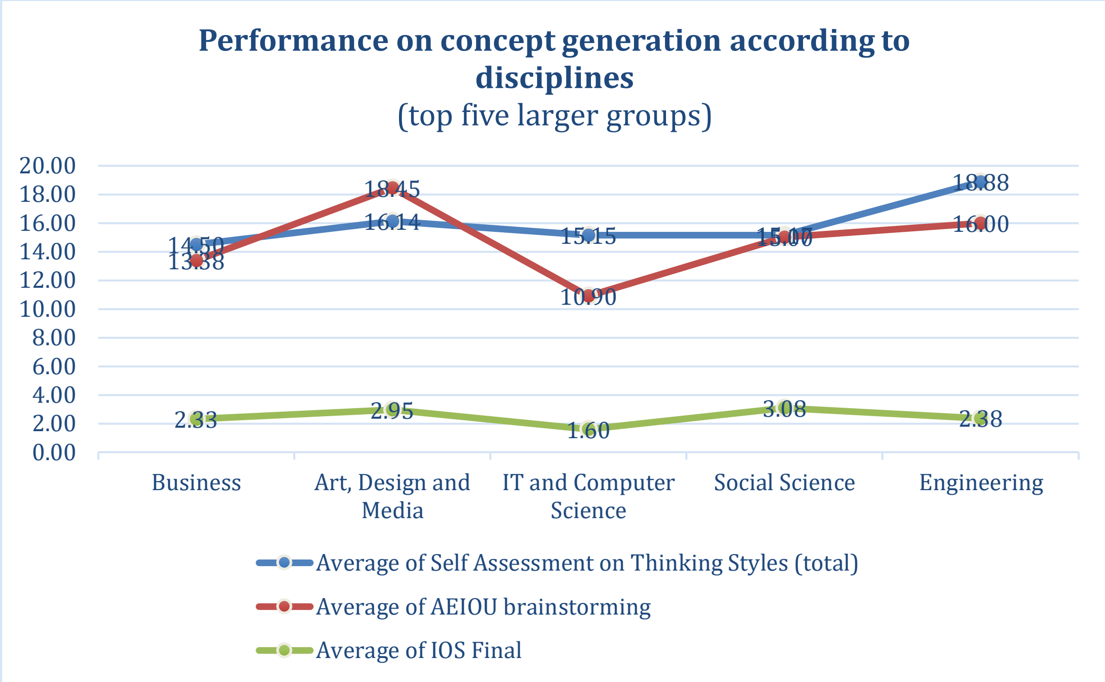


Figure 6.8 Comparison of the top five disciplines with the highest number of participants and their average performance scores for (i) self-assessment of individual thinking preferences; (ii) AEIOU brainstorming (the higher the score, the greater the number of items generated); and (iii) 'interactiveness', 'objectness' and 'situatedness' (IOS) evaluation.

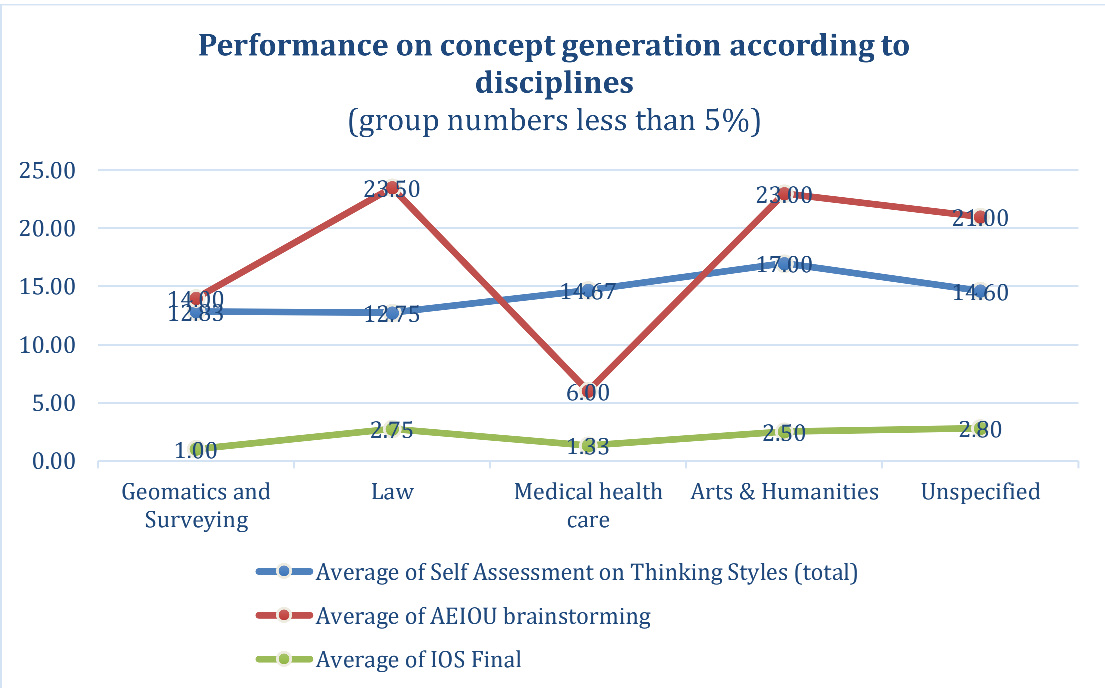


Figure 6.9 Comparison of the other disciplines with the smallest number of participants (less than 5% of the total) and their average performance scores for (i) self-assessment

of individual thinking preferences; (ii) AEIOU brainstorming (the higher the score, the greater the number of items generated); and (iii) ‘interactiveness’, ‘objectness’ and ‘situatedness’ (IOS) evaluation. The ‘interdisciplinary’ discipline was excluded as the data were missing.

6.4.1 Thinking preferences, imageability and prototype-ability

The literature review discussed the potential concepts related to **prototype-ability** and showed that it was strongly related to the **imageability of verbal design concepts**. The main question was how the **imageability** (concreteness of the description of verbal concepts) was correlated with the **performance of prototyping** (scenario sketching in this case).

To examine in detail the factors affecting the performance of IOS, another question was whether **visual or verbal thinking contributed to the performance of prototyping**.

In majority of my participations in co-creation workshops, it is a normal practice that the organizers as well as the participants believe on having member with art and design background can benefit to the creativity and or ideas representation of the group work. The study shows that it is not very significant (figure 6.1). Other participants from non-design disciplines also performed well. And the self-assessment on personal thinking style (intelligence profile on the tendency of mastering visual and verbal thinking) is not accurate. A personal assessment with scientific measurement may be used to further prove the correlational study in future.

Three largest disciplinary groups in the test were ‘Business’ (twelve participants), ‘Art, Design and Media’ (eleven participants), and ‘IT and Computer Science’ (ten participants).

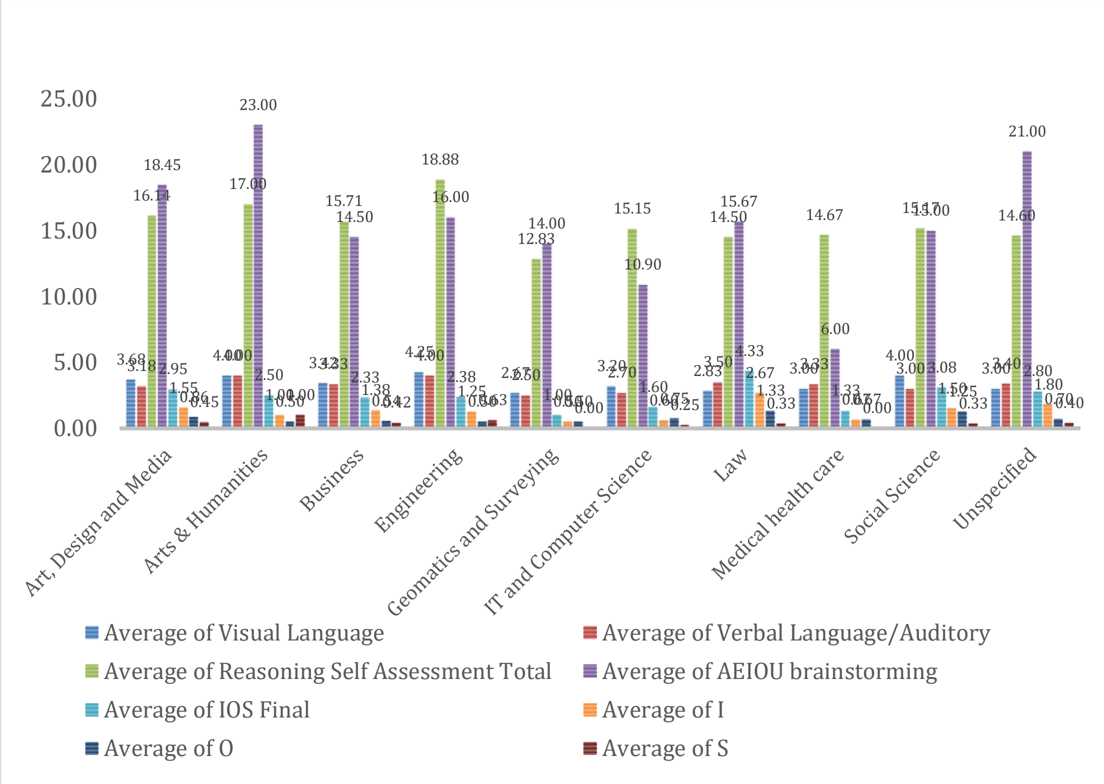


Figure 6.10 Comparison of the average scores for visual and verbal preferences, AEIOU and IOS performance.

6.4.2 Conclusion of the AEIOU task

This project was based on the premise that people with art and design training (with comparatively more creative methods and experience in brainstorming) should perform better in concept generation or brainstorming exercises. According to the data, the informants studying law (three people) had the highest average AEIOU score with 23.5 items. The second highest score was arts and humanities (one person), with 23 items. Art, design and media (11 people) reached an average of 18.45 items. Unspecified samples were not counted in this study.

The results showed that people trained in art and design did not perform as well as those in other disciplines. There were fewer people studying law and humanities. The results may vary with a larger sample. One possible explanation for these results is that the AEIOU exercise was based on textual language, thus the participants who excelled in verbal thinking may have outperformed non-verbal thinkers.

According to the juxtaposition of thinking style indicators, AEIOU scores and IOS scores, there was a **strong positive relationship**, in particular in the top five disciplines with the largest number of participants. It is possible that other disciplines, such as ‘medical healthcare’ (5%), ‘geomatics and surveying’ (5%), ‘law’ (5%) and ‘arts and humanities’ (2%), may demonstrate a consistent positive relationship with a larger sample. Therefore, it can be concluded that the mean of the overall self-assessment of the participants’ thinking preferences (the five intelligence profiles) is consistent with their concept generation performance (the AEIOU) and shows a slightly similar trend in IOS scores, although it is not obvious. Further studies are needed.

Chapter 7 Conclusions

This chapter presents the results contributing to the description of the model based on the concept ‘prototype-ability’ for the improvement of the early phase prototyping process through **(i) the review of the 12 common cases of participatory design workshops** to examine the problems and opportunities related to early phase prototyping; **(ii) the extension of the framework** for the effective use of the tools and techniques of participatory design; and **(iii) the design task** to investigate the problems in the development of the ‘prototype-ability’ descriptive model for an effective early phase prototyping process. At last sessions, contributions and implications, and the limitations and directions of future research are discussed.

7.1 Inspirations based on the 12 case studies

Here are the aggregated results of my reflections as a workshop facilitator and participant, and the opinions of others on coaching workshop participants from different disciplines and backgrounds.

Four perspectives are used to describe the **early phase concept prototyping process in participatory design processes**. **First**, it is useful to select or customize the **appropriate prototyping tools/methods** to **initiate and facilitate continued group communication**, as a design workshop is context-dependent and time-limited. For instance, unlike a design firm, it is unrealistic to recruit many colleagues (or different stakeholders) from the same organisation to attend a design workshop for a few days or weeks. In addition, the facilitator should assume that different participants have various preferences, values, and even different agendas/expectations. Each workshop has its objectives with a **unique prototyping process**.

Second, more participants can ensure a variety of inputs and **collective ownership building**. Prototyping collectively is also essential and useful for collecting ideas and consensus. **The prototyping process is a dialogue process** in which both internal (the participant’s oneself) and the external (amongst the participants) interactions happen as the description of dual coding theory discussed in Chapter five. According to the dual coding theory, the workshop participants can acquire ownership through two stages. First, it is an **intra-personal dialogue** in which the establishment of a bigger picture about the associative network of and linkage amongst the verbal concepts (in the verbal system of one's brain) and the material structure (in the non-verbal system of one's brain) related to the design topic of discussion is constructed. Second, an **inter-personal dialogue** is constructed through the participation of expressing and creating ideas in a group in which mutual understanding and or agreement is achieved.

Third, prototyping involves the **processes of analysis and synthesis, in which the representation of abstract concepts and concrete concepts takes place in turn.** It is a process in which the participants **perceive meanings and inspirations**. **Fourth**, this work focused on the **collaborative working environment with participants from multidisciplinary backgrounds**. Professional product designers are generally well trained and equipped with advanced prototyping skills, such as accuracy in sketching and better knowledge of material choices and processing techniques. People either excel in verbal thinking (e.g. an excellent oral presenter) or visual thinking (e.g. a skilful visualizer) and can dominate the group discussion during collaborative work. If most participants, regardless of their strengths, can express their thoughts and meanings to others comprehensively, as clearly and as earlier as possible, the quality of engagement and innovation will be ensured. The **criteria for selecting appropriate prototyping tools/methods** should take into account the participation and performance of participants from different backgrounds.

7.1.1 Summary of the case studies

The review of the 12 selected cases was useful to describe the characteristics of the transition from initial design concepts to early phase prototyping. The section below summarises the issues, including design problems and process characteristics, leading to effective early phase prototyping.

Twelve cases provided a **general picture** of the **development of design/design thinking workshops in the field of social innovation initiatives** in the last 5 years.

Each workshop had a different duration and focus (see Table 4.1 in Chapter 4). The samples also included workshops organised and coordinated by experienced workshop facilitators from abroad (e.g. the Helen Hamlyn Centre for Design, Royal College of Art) and important local NGOs or pioneers of social innovation (e.g. the Jockey Club Charities Foundation, the Hong Kong Design Centre, the Design Institute for Social Innovation of The Hong Kong Polytechnic University, the Hong Kong Sheng Kung Hui, the Welfare Council and Hong Kong Christian Service). Insightful similarities and differences in aspects related to the factors affecting effective early phase prototyping were expected to be examined. The following table summarises the key aspects of the 12 cases from the following perspectives.

(i) Problems and constraints in the design process.
(ii) The characteristics of design workshops adopting prototyping approaches.
(iii) The type of prototyping approach and its relation to the above problems.

Table 7.1 Summary of the analysis of the 12 cases (in Chapter 4).

Cases	Types	Summary of issues affecting early phase prototyping process
I	Co-creation Programme 2015 (Post-it and sketching as tools in the prototyping process)	• Lack of real representatives (or real users). • Knowledge in different contexts was needed. • Designer dominated. • Different levels of professional knowledge affected the level of participation of different non-professionals. • Concept generation and quick prototyping process were short.
II	My Quality Home Living – The Elderly Creative Workshop (prototyping process driven by visual tools)	• Misalignment and misorientation: The participants had difficulty manipulating the furniture or product icons accurately. • Visual information facilitated trial and error: important for concept exploration and modification. • Visual representation helped articulate the user experience (intangible experience): Compared with a normal questionnaire with verbal clues, more accurate user perceptions of their needs were collected through graphical or visual representations, in particular the

		concepts related to the spatial relationship between users and objects, the goal being to create a user experience. • The participants did not have the exact or correct experience related to the research context.
III	Preferable Elderly Home Design Prototyping Approach (3D tool)	• Prototyping using predefined modelling materials enabled creative participation. • Prototyping a familiar space/design enhanced reflection. • The prototyping process worked as an open research approach.
IV	Jockey Club Retreat Workshop	• The participants differed in visual-spatial performance. • The participants explored the design iteratively.
V	KODW 2017 Elderly Design Workshop by RCA	• User journey or scenario prototyping used for concept integration by a larger group of participants. • Scenario prototyping helped develop (i) concepts focused on problem identification, (ii) concepts focused on service solutions and (iii) concepts focused on product solutions. • Concepts with concrete actions. • Concepts with abstract directions.
VI	The Park Lab 2017	• Most tools used in the workshop were text based. • Abstract concepts could not be easily imagined by inexperienced people. • Prototyping was a learning process for tackling abstract or unfamiliar experiences.
VII	PolyU x HHCD Healthy Ageing in Hong Kong: Hong Kong Care Homes	• User research could not ensure appropriate or creative insights. • No early prototype testing limited the possible solutions or creative concepts.
VIII	Intergenerational Game Design Workshop with and for the Elderly	• A clear framework led to earlier prototyping. • A range of prototyping activities, from a simple scenario (single person experience/single product system) to a complex scenario (collective experience of people/product-service system involving various levels of stakeholders).

IX	WeDesign Programme by JCDSI	• Incomplete participatory design approach. • The participants (students) lacked concrete and precise experience in furniture design and materials processing know-how. • There were obstacles to prototyping.
X	Workshop for Community Service Platform Planning (Yi Pei Square)	• Lack of description of objects or services. • Lack of details of user experiences/interactions.
XI	Elderly Service Review Workshop for Social Workers	• The concept mapping tool facilitated clustering. • Perceptual mapping facilitated clustering activities by a group of participants, leading to effective early prototyping. • Service design prototypes varied from simple and concrete experiences to complex and abstract experiences.
XII	Elderly Service Design Workshop for Home Services Team	• Concept mapping contributed to effective clustering in a holistic way in a theoretical framework. • An effective workshop tool should allow the participants to be confident. • The concept mapping tool as a tool for analysis and synthesis enhanced early prototyping. • The workshop participants with different backgrounds and agendas needed specific effective collaboration and communication.

7.1.2 Problems with clustering the case studies

The 12 cases had different objectives, but the learning experience provided useful information after clustering the identified problems/aspects. Fifteen concepts were identified. The results corroborated the model’s argument regarding the effective early phase prototyping process described in other sections.

Table 7.2 Summary of the coding results for the characteristics and problems related to early phase prototyping identified in the 12 case studies.

Coding of the characteristics and problems of early phase prototyping process	Descriptions of the problems or issues
1) Level and grouping of the participants' representation in the design process	• Lack of real representatives (or real users) in the prototype process. • Different combinations of participants from different backgrounds affected the results of the workshop. • Involvement in the prototyping process was not complete/partial participation at certain stages.
2) Constraints induced by professional skills	• Designer dominated. • Different levels of professional knowledge affected the level of participation of different non-professionals.
3) Constraints induced by unfamiliar knowledge	• Knowledge in different contexts was needed. • The participants did not have direct experience of the research context. • The participants (students) lacked concrete and precise experience in furniture design and materials processing know-how. • This became an obstacle to prototyping.
4) Time limitations	• Concept generation and quick prototyping process were time limited.
5) Different strengths in visual-spatial reasoning	• Misalignment and misorientation: The participants had difficulty manipulating the furniture or product items accurately.
6) Visual approach for active and effective analytical and exploratory prototyping tasks	• Mapping visual and verbal concepts facilitated analytical and synthesis activities, in which trial and error could be carried out for concept exploration and modification. • Visual representation helped articulate the user experience (intangible experience). • Effective mapping tools enriched participants' confidence. • The participants differed in visual-spatial performance. • User journey or scenario prototyping used for concept integration by a larger group of participants. • Scenario prototyping helped develop (i) concepts focused on problem identification, (ii) concepts focused on service solutions and (iii) concepts focused on product solutions. • The concept mapping tool facilitated clustering. • The theory-based concept mapping tool led to effective concept identification/clustering. • Perceptual mapping facilitated clustering activities by a group of participants, leading to effective early prototyping.
7) Advantages of adopting physical models in research and design phases	• Prototyping using predefined modelling materials enabled creative participation. • Prototyping a familiar space/design enhanced reflection. • The prototyping process worked as an open research approach. • The participants explored the design iteratively.
8) Aspects of concreteness	• Concepts with concrete actions.
9) Aspects of abstractness	• Concepts with abstract directions. • Abstract concepts could not be easily imagined by inexperienced people

10) Concept development process driven verbally	• Most tools used in the workshop were text-based approaches. • Lack of description of objects or services. • Lack of details about user experiences/interactions.
11) Prototyping as a research approach/design hypothesis	• Prototyping was a learning process for tackling abstract or unfamiliar experience.
12) Appropriate insights for effective prototyping	• User research could not ensure appropriate or creative insights. • No early prototype testing limited the possible solutions or creative concepts.
13) Theoretical framework for the enhancement of early phase prototyping	• A clear framework led to earlier prototyping.
14) Prototyping process with a holistic approach	• A range of prototyping activities, from a simple scenario (single person experience/single product system) to a complex scenario (collective experience of people/product-service system involving various levels of stakeholders). • Service design prototypes varied from simple and concrete experiences to complicated and abstract experiences.
15) Level of participation in the design process	• Incomplete participatory design workshops limited the creative outputs of the participants in terms of quantity and quality.

7.2 The prototype-ability model for early phase concept prototyping in participatory design

Early phase product concept prototype-ability is the primary driving force to support iterative concept development in the co-creation process (or participatory design process) as stated at the below diagram of a standard complete cycle of a participatory design or co-creation workshop. As mentioned earlier, there is a spectrum of different types of prototypes which represents various fidelity or resolution for supporting different experience such as a scenario of an innovative wheelchair which can support the evaluation of user experience in a different situation or environment, or a mock-up to prove the ergonomic performance while the user sits on it. The stages highlighted in green indicate the majority and intensive collaborative encounters (Manzini, 2015), such as the creative activities that make abstract things visual and tangible. The scope of the early phase product concept process falls into this range of activities. The manufacturability of a prototype and final product design is not concerned in the framework of this study.

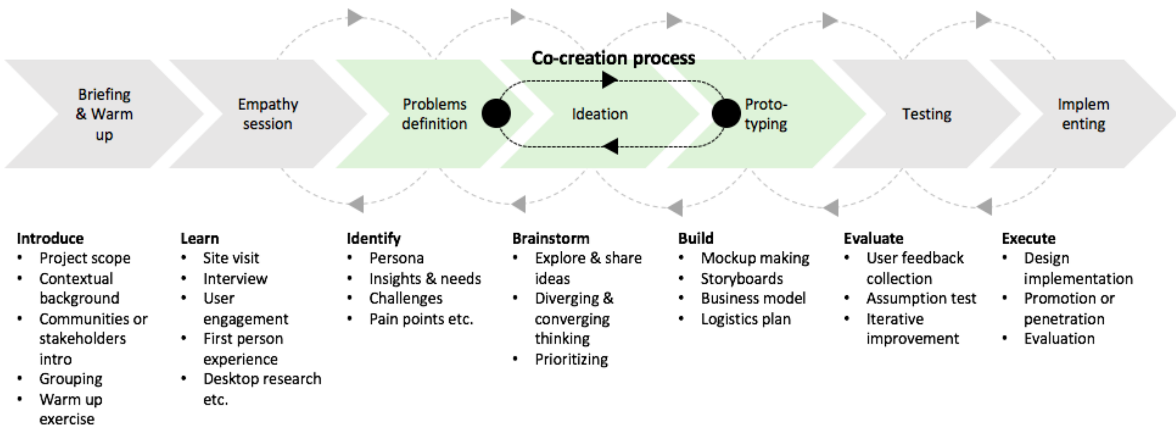


Figure 7.1 The complete process cycle of a participatory design workshop. The stages in green carry out the majority and intensive collaborative encounters such as the creative activities that make abstract things visual and tangible.

In the thesis, the concept prototype-ability focuses on the facilitation of collaborative encounters as mentioned in Chapter one (Manzini, 2015) in which sharing values including time, care, experiences and expertise are the core of the design actions in the collaborative design process. The value is expressed and co-constructed through the dialogue building which is key to successful prototyping and participatory design. Sanders, Brandt and Binder (2010) elaborated on the cooperative aspect of participatory design using what Ehn (1988) called the **prototyping of shared artefacts as a centrepiece of design dialogues**. According to Sanders, Brandt and Binder (2010), the origin of the main tools and techniques of participatory design lies in **(i) scenario techniques** derived from drama and forum theatre; **(ii) design games** with materials and rules to facilitate design dialogue; and **(iii) prototyping techniques** enabling participants to jointly construct prototypes in a group with different professional backgrounds or interests.

7.2.1 Dimensions and parameters of the framework

Based on the literature review, empirical findings and critical reflections on workshop facilitation, I propose a **four 'S' engagement model** on enhancing early phase prototyping that can support effective collaborative encounters. It aims to prepare a workable and sustainable method that the workshop planner and facilitator can ensure the effectiveness of the **collaborative imagination and value exchange** as proposed by Manzini (2015). The model should address the following dimensions:

i) Select appropriate workshop methods and tools.
ii) Stimulate awareness on the state of transition between abstract and concrete concepts through different methods.
iii) Strategize the workshop process with a sensible and flexible plan that addresses the people, approach, tools, and organisational factors in the early phase concept prototyping process.
iv) Stimulate the prototype-ability through the ISO enable model in terms of interactiveness, objectness and situatedness. It aims to make sense of the complexity of the past, present, and future settings explicitly.

7.2.1.1 Framework for organising tools and techniques in participatory design

The framework proposed by Sanders, Brandt and Binder (2010) suggests **three dimensions** to describe the tools and techniques used in the participatory design process, including when to use them and for what purposes.

<u>Dimension I: 'Form'</u>

'Form' describes the types of actions interacting with the participants in the workshop activity. The form involves **(1)** the **'making'** of tangible things, such as 2D collages, 2D mappings and 3D mock-ups; **(2) 'telling'** concepts, including talking and explaining through diaries, daily log or idea cards with writing, drawing and images; **(3) 'enacting'** with a participatory experience, including acting and playing using board games, props and future settings/situations.

<u>Dimension II: 'Purpose'</u>

'Purpose' describes the rationale for adopting the tools and techniques with four factors: **(1) probing** the participants; **(2) priming** the participants to better engage in the domain of interest (and build ownership); **(3) understanding** the participants' current experience; **(4) generating** future ideas and design concepts, such as future scenarios.

Dimension III: ‘Context’

‘Context’ refers to where and how the tools and techniques are applied with four parameters: **(1) group size and composition**; (**2) face-to-face vs. online interaction**; **(3) venue**; and **(4) stakeholder relations**.

The following diagram illustrates the organisation framework and shows how the three dimensions relate to other factors/parameters.

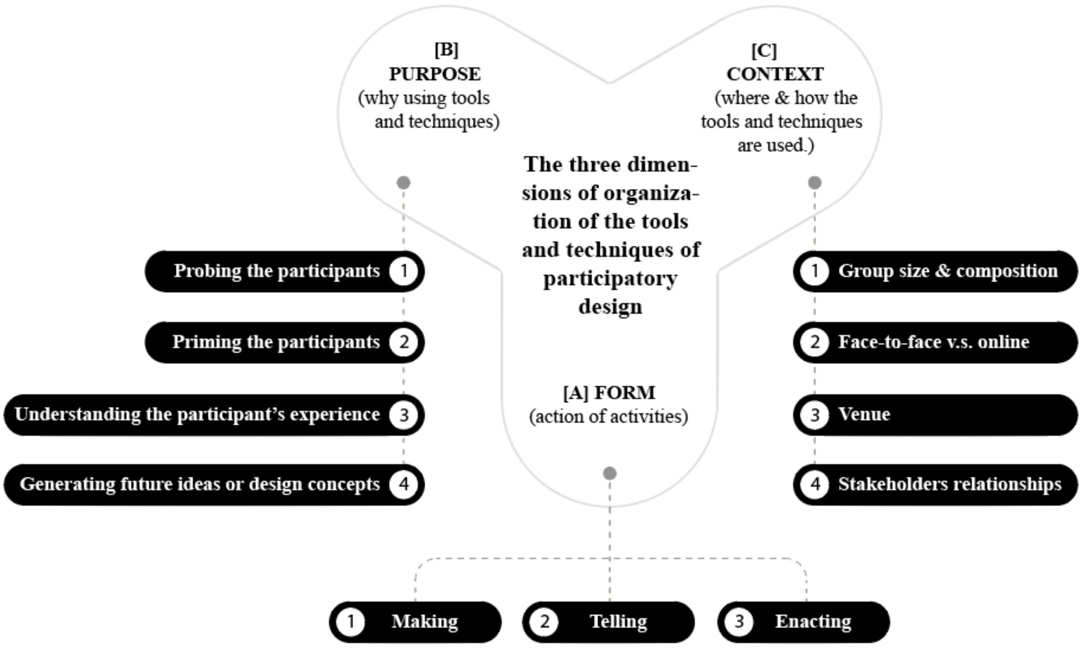


Figure 7.2 Framework for organising tools and techniques in participatory design (Sanders, Brandt & Binder, 2010). Source: Author.

The three dimensions of the framework are useful for helping workshop planners/facilitators make the rights choice of tools and techniques for participatory design workshops. From the perspective of improving early phase concept prototyping, the framework is useful for supplementing the results of the 12 selected case studies.

Table 7.3 Framework for organising tools and techniques for participatory design with additional strategies or concerns for effective early phase concept prototyping.

<table>
<tr><th colspan="2">Criteria on the selections of tools and techniques of participatory design</th><th>Strategies or concerns for effective early phase concept prototyping</th></tr>
<tr><td rowspan="3">(A) Form</td><td>Making</td><td rowspan="3">(2) Constraints induced by professional skills
(3) Constraints induced by unfamiliar knowledge
(4) Time limitation
(5) Different strengths in visual-spatial reasoning
(6) Visual approach for active and effective analytical and exploratory prototyping tasks
(7) Advantages of adopting physical models in the research and design phases
(8) Aspects of concreteness
(9) Aspects of abstractness
(10) Concept development process driven verbally
(12) Appropriate insights for effective prototyping</td></tr>
<tr><td>Telling</td></tr>
<tr><td>Enacting</td></tr>
<tr><td rowspan="4">(B) Purpose</td><td>Probing</td><td rowspan="4">(2) Constraints induced by professional skills
(3) Constraints induced by unfamiliar knowledge
(4) Time limitation
(5) Different strengths in visual-spatial reasoning
(7) Advantages of adopting physical models in the research and design phases
(8) Aspects of concreteness
(9) Aspects of abstractness</td></tr>
<tr><td>Priming</td></tr>
<tr><td>Understanding</td></tr>
<tr><td>Generating</td></tr>
</table>

		(10) Concept development process driven verbally (11) Prototyping as a research approach/design hypothesis (12) Appropriate insights for effective prototyping **Suggestions:** (13) Theoretical framework for the enhancement of early phase prototyping (14) Prototyping process with a holistic approach
(C) Context	Group size and composition Face-to-face vs. online Venue Stakeholder relations	(1) Level and grouping of the participants' representation in the design process (4) Time limitation (15) Level of participation in the design process

7.3 IOS enabling model to facilitate the prototype-ability of early phase product concept in co-prototyping process

According to the previous section on the content analysis of the design task (58 valid samples), the coding results for the performance of early phase concept prototyping were summarised in **three concepts**- ‘**interactiveness**’, ‘**objectness**’ and ‘**situatedness’** (‘I’, ‘S’ and ‘O’ is the abbreviation). The descriptors can explain the motivations of the designers (and participants) who are addressing or challenging the design problems while generating the creative outputs verbally (e.g. AEIOU exercise) and visually (e.g. sketching or scenario visualization) in the standard early phase design concept prototyping process. Although the design task carried out the measurement on the performance of individual creative outputs, it is assumed that the individual verbal and visual outputs are the essential elements for the communication and co-construction of collaborative works with other participants.

An alternative to be used as a measurement tool, the three descriptors are useful for guiding designers or workshop participants who can articulate the design concepts in perspective of enhancing the opportunities to co-create a tangible prototype for iterative development. Thus, in other words, I propose to formulate a holistic model represented as the three descriptors in terms of three dimensional factors that contribute to appropriate **collaborative prototyping** (or short abbreviation called **co-prototyping**). The model as shown at the below example (Fig. 7.2) illustrates that the concept ‘prototype-ability’ is constituted by three distinct dimensional planes which represent three matrixes (5 x 5 boxes) formed by three pairs of descriptors. They are **‘interactiveness - objectness’ (IO), ‘situatedness - objectness’ (SO)**, and **‘situatedness – interactiveness’ (SI)**. On the other hand, each axis (total three) shows the continuum from abstract concept (outer range of the model) and concrete concept (centre of the model). The example showed that the result of the application of the model could be used for the evaluation of a design concept for prototyping. First, the accessor counts all IOS related elements then sorts the elements according to the levels of concreteness and abstractness in a scale from 1 to 5 (1 is the most abstract concept, and 5 is the most concrete concept). The most concrete concepts (both I, O, and S) can be marked in the middle of the diagram, and the least concrete concepts (more abstract concepts) can be placed at one level away from the middle according to the concreteness.

For instance, the three pairs of descriptors and examples are listed at below:

i) Example of IO: The seating design supports two users who can sit at the opposite which can afford face to face chatting (interaction).

ii) Example of SO: The seat is installed under a big tree that provides shading.

iii) Example of SI: The shading provided by the tree affords a cooler leisure environment, relax and comfortable resting for a longer time under strong sunlight.

Regarding the indication of the concreteness of one concept (the box at either one of the dimensions), the maker can print the diagram or directly work on the computer and fill the boxes by a colour or a symbol. In a collaborative design workshop, the accessor can prepare a print of the diagram that is big enough for displaying a few dozens of post-it notes. The team can directly put the post-it notes generated by the workshop participants on the matrix boxes accordingly. The major challenge is the consistency of the assessment. The mapping or matrix is a perceptual experience of a group of people. I suggest two methods to ensure the proper assessment. First, a single assessor can compare a few more cases to monitor and align the distributions of the concreteness. Second, the team may invite at least three assessors to rate the same case and compile a final mapping.

This model can also reflect the phenomenon that the concrete concepts of the IO, SO, or SI related elements usually having a **reciprocal relationship**. For instance, the quality of SO and SI can affect the interactive quality of IO. There is an advantage to the AEIOU tool which cannot illustrate the relationship of individual elements as, for instance, ‘activities’ and ‘interaction’ are recorded or categorised separately in two clusters. The representation approach (five columns to indicate the possible elements of a scenario design or a prototype) cannot show the overlapping meaning of the elements. Thus, if the two concepts show a close relationship, they should be placed adjacent to each other on the ISO enabling model.

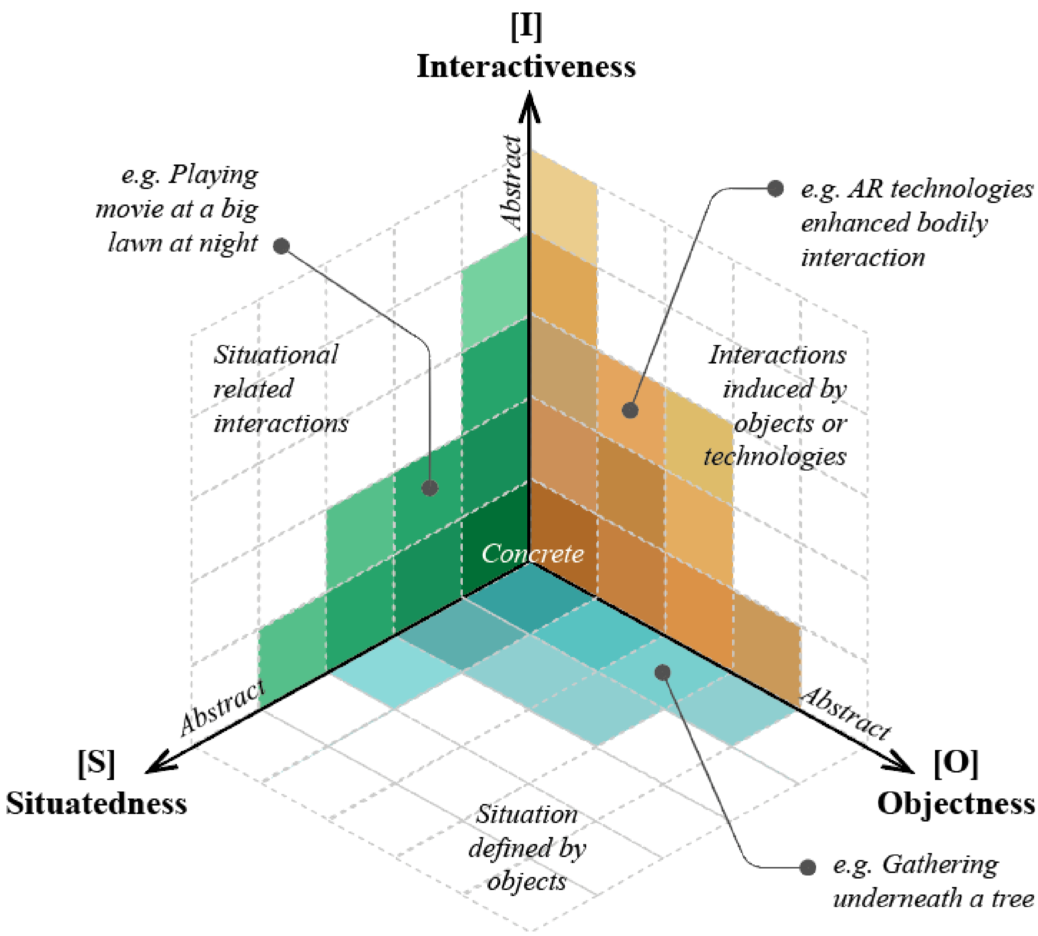


Figure 7.3 The IOS enabling model for the enhancement of prototype-ability at the early phase product concept generation process. The above diagram demonstrates an example of the result of assessing the performance of a design concept (scenario and description of concept) in the three prototype-ability's descriptors (interactiveness, Objectness, Situatedness) which are illustrated in three dimensional planes.

In application, this model can replace the AEOIU method or other concept's brainstorming tools to facilitate concepts generation and engagement. The IOS model covers similar contexts of the AEIOU method, including the concerns of 'interactions' (in interactiveness), 'objects' (in 'objectness'), and 'environment' (in 'situatedness'). It didn't directly cover the elements of 'activities' and 'users'. In practice, the concepts related to activities and users (or stakeholders) are directly incorporated into a three dimensional planes. Therefore, the IOS model would not induce the common problem of AEIOU- people always mix up the definition of 'interactions' and 'activities'. The IOS model requires two items less during concept exploration (i.e. filling the AEIOU table) and induces less confusion and less time consumption. The participants can write or draw (or stick the memo) the concepts on the grids of the planes. This action is the key contribution of the model which plays a role in mapping the abstract and concrete concepts as well as facilitates the participants to discuss and make modifications collaboratively. The participants can transform the ideas into a more concrete one from abstract concepts (placed at the outer range).

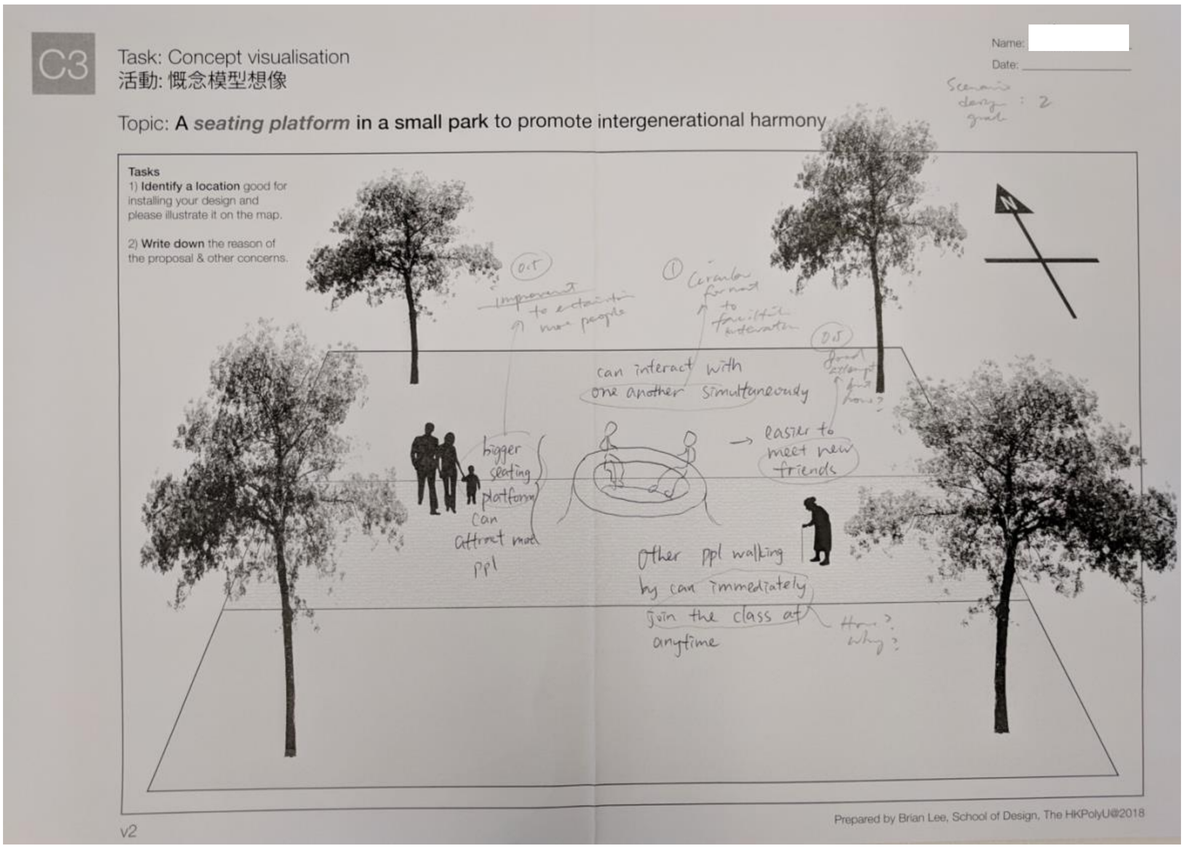


Figure 7.4 The sample N58 is a case showing a very high AEIOU result (the second highest) and mediocre result in ISO score (below the mean).

A real application of the IOS enabling model was demonstrated with the sample N58 (Figure 7.4) at below (figure 7.4). It was evident that the IOS elements identified from the result of the design task are minimal – only five elements were generated. According to the mapping's result, the facilitator can suggest the participant to develop the concept further through (i) expanding the areas lacking exploration and (ii) the discussions with teammates to expand and clarify the existing concepts from the abstract level to the concrete level. Once **more and closer the elements towards the middle of the matrix**, higher the concreteness and detailed information are there to ensure **effective**

communication amongst the teammates, concrete prototyping at the next phase, and **co-constructed learning experience with strong ownership** of the project. In other words, the **prototype-ability of the design concept** is enhanced.

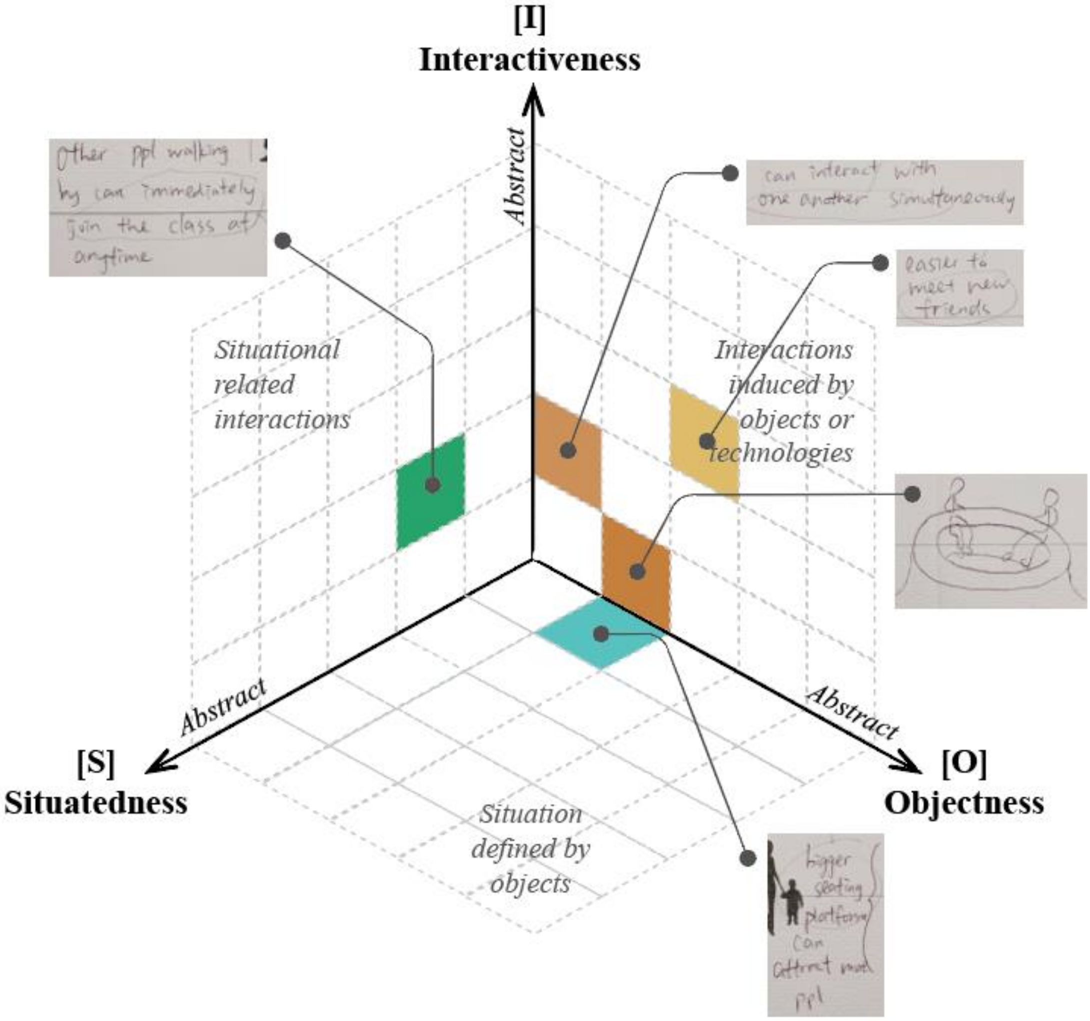


Figure 7.5 The above matrix demonstrates the distributions of five IOS elements (the early phase design concepts generated by the informant N58) according to the IOS enabling model.

At last, the results showed that 'interactiveness' plays a more important role than 'objectness' and 'situatedness' in the process of developing concrete prototypes. Elements on the user's interaction with the object and or environment can enable the designer or participants to imagine and develop the necessary factors – the relevant objects and or situational factors that induce the required interaction. 'Interactiveness' contributes more to 'imageability' than the other two attributes. All three attributes are not necessary for high prototype-ability.

7.3.1 Discussion

1) The data generated an important observation. Sketching is the major early phase concept representation method in this study. Why did many informants rates (figure 6.8 and 6.9) their visual thinking ability as high (self-evaluation of good visual memory and feeling comfortable thinking and solving problems visually) but have weak sketching skills? One of the reasons is that many participants are not designers. And having good visual memory (tends to good at visual thinking) doesn't mean that they receive proper drawing training or good at manipulation of a pen which is affected by the fine motor skill of fingers (hands-eyes coordination).

2) Meanwhile, according to the result of the AEIOU exercise, designers may not necessarily perform well in AEIOU and or IOS scores though they have assumed a creative person. Participants (including designer and others) weak in verbal thinking may have difficulties to elaborate their concept in mind explicitly and detailly through writing during a short workshop period.

3) Furthermore, neither the facilitators nor the participants address the significance of concreteness and abstractness to the development of verbal and visual concepts and the prototype-ability. The proposed IOS enabling model can enhance the co-creation workshop's instruction process and participant's engagement experience collectively.

4) In the AEIOU task, the 'interaction' item had a stronger correlation with better scenario design performance. This may be because people who generate more abstract verbal concepts produce weaker scenario designs. In general, the participants demonstrated limited conceptual associations with the user experience and the quality of interactions with 'objects' and 'activities'. This work had two limitations: (i) the participants may achieve better results if they have more time; and (ii) the use of Chinese for instruction and outputs may be more direct and easier for Chinese informants.

5) Comparing Group A (10-20) and Group B (60+), Group A generated more concepts with more concreteness in general, and the scenario design results were also better. The time factor may not have been an issue in this case (Group B), as both the designer and non-designer participants exhibited poor performance in the sketching task.

6) The participants who generated abstract concepts (interaction) and created a design with a basic structure and a lack of quality contributed to the intergenerational design (e.g. Sample N44). They had either a weak imagination, a lack of references in everyday life or a lack of creative training, such as forced association exercises.

7) In conclusion, referring to Sample N48, **abstract concepts** (e.g. the 'interaction' item in the AEIOUS task) usually **led to unspecified scenario design** and the design did not show enough elements for prototyping (such as the process of engaging people, attracting people). People may not be used to asking 'how?' or 'why?' and may not know how to articulate the details of the design features.

8) **Visual tools facilitating concrete thinking or concept development** were identified in the study (e.g. Sample N48). Indeed, some designers developed more concrete concepts through visual means than through verbal means.

9) **Few new concepts** (for intergenerational park furniture design) were identified. The participants performed better in the brainstorming activities, including many abstract 'interaction' descriptions and limited 'object' visualisation. For instance, the participants drew a chessboard but did not further explore or explain how this object can facilitate communication or a new playful experience to meet the theme.

10) In general, **low prototype-ability** was identified. This may be due to the fact that higher prototyping scores require an emphasis on the design parameters of a concept (e.g. N55). A weakly visualised specific feature made it difficult to (i) envision how to plan or make the physical prototype; and (ii) inspire or communicate with other stakeholders the effect of the concept.

11) **Abstract product category levels** reduced prototype-ability. Many participants produced sketches of objects with a relatively high abstract level in this product category, such as a table (which is very generic). A coffee table made of wood is more specific and better meets intergenerational needs, thus it can be considered a higher prototype-ability.

7.4 Summary of key findings

The research scope was limited to the investigation of proof-of-concept prototypes, in particular the transformation of verbal concepts into visual concepts during the early ideation stage. I regarded this as an appropriate research target leading to a more detailed and effective participatory design. The following discussion further justifies this perspective.

Prototyping is an approach to one of the three creative acts of making, namely probes, toolkits, and prototypes, to enable designerly ways of doing research in response to design intent for people and with people for a near and/or speculative future (Sanders & Stappers, 2014). It has increased over the last 10 years or so.

In the early design process, prototyping is widely used for different goals (settings), such as academic training for students (idea exploration and process learning), social innovation (community engagement for communities, NGOs and governments through workshop participation) and business innovation (stakeholder participation to propose administration, service or product innovation). Prototyping is also an emerging technique to facilitate cooperation or collaboration. It is an effective approach for functional evaluation at the end of the design process and in the early design phase, as suggested by Sanders and Stappers (2014).

Focusing on the early design process, what are the characteristics of prototyping, especially for co-creation workshops? How can we ensure that participants from different backgrounds contribute as much as possible? Generally, people look for a precise procedure for co-creation or co-design training. However, the prototyping process is often poorly defined. As a result, this research identified key concepts to explicitly describe the quality of prototypes in the early stage of design. They are developed in the following sections.

7.4.1 Imageability and situatedness

Main problem in design workshops –Mental concepts can weaken mutual understanding

The main problem I identified in most of the design thinking workshops or design concept brainstorming activities is that expressing a concept (mental representation) using a verbal/textual description is a common approach of designers (workshop participants), who write the concept on a Post-it note, paper or whiteboard. Designers sometimes also illustrate the concept quickly. If designers describe the concept with a more abstract word that is a generalisation of the concept (high-level thinking), the verb cannot induce specific information about an object or event with a relatively concrete understanding for designers and other viewers. Thus, it can have a negative effect on the group's understanding and it cannot guarantee that the participants share the same or similar experience of this concept.

There is no doubt that prototyping is key to ensuring product appropriateness and reducing the negative effects of the product implementation phase (many design firms and design workshops also emphasise this). The early design phase requires appropriate prototyping. In addition, prototyping is not arbitrary and requires a specific framework and instructions.

This research showed that 'imageability' and 'situatedness' are two key concepts that can extend the instructional design theory to facilitate the use of prototyping in the early design phase.

7.5 Contributions and implications

To promote a **human-centred approach**, the implementation of the participatory design process has become more prevalent in design, commercial and government organisations at the international (Greenbaum, 1993; Emspak, 1993; Demirbilek & Demirkan, 2004) and local levels (Community Museum Project, 2010; Lee & Chan, 2013). Creating a design workshop for participants from multidisciplinary backgrounds and with diverse agendas is more challenging than creating a general design workshop for people with similar backgrounds. To develop an appropriate final deliverable, it is essential to plan ahead all expected outcomes; for instance, some participants may not perform well in certain tasks. Some people are good at verbal thinking and some are visual thinkers. Some are equipped with modelling skills and others are better at abstract thinking. However, the findings of the case studies only examined the problems encountered during the early phase concept prototyping stage.

A workshop is a platform for facilitating interaction (physical and mental) and learning. For instance, in the 12 selected workshop training activities discussed earlier, identifying, classifying, demonstrating, producing, selecting, comparing and designing were the actions of short exercises that could be executed by a single participant or a group of participants. Splitting the entire design process (from research to final execution) into several well-defined tasks is also a common practice in most workshops. Usually, in the early design phase, user research with an empathy approach (e.g. on-site observations, user interviews or user engagement), idea brainstorming (e.g. ideation with stakeholders) and prototyping (e.g. sketching, storyboard, scenario study, user testing through mock-up or simple prototype making) are common workshop components, which are useful for collecting new concepts or insights and enabling ownership of participants or communities. This is also why most participatory design approaches **focus on the early design process**. However, actual and detailed production plans and prototypes (high fidelity models) rarely occur in design workshops.

Brooks-Harris and Stock-Ward (1999), Dearling (1992) and Steinert and Ouellet (2012) discussed and elaborated a comprehensive description and instructional guide for designing general workshops, including preparation, creation of learning activities and workshop plan and facilitation and evaluation methods. This thesis provided a deeper understanding and insights into the concepts of the learning experience and prototyping approach and informed the role, nature, and definition of design workshop preparation in the future.

7.5.1 Implications for social innovation projects

Prototyping in the social innovation process is influential, in particular, to promote participation, empowerment, and ownership, and to test new hypothesis collaboratively. Therefore, a prototype should be able to enhance and provoke collaborative creations in which **social-related scenarios** can be addressed, such as **understanding the conflicts between top-down policies and bottom-up needs**, **envisioning social value change**, and **empowering minority or specific communities**. All the agendas require the participation of different stakeholders having diversified mindset or value which may seriously affect the effectiveness of the co-creation process. Thus, communication and design tools to address or support the exchange of social-related concepts are required. Unfortunately, the previous proposed IOS enabling model, the same as other tools such as the AEIOU framework, cannot address societal information explicitly such as the concept related to social value change which can only be clustered into the dimension of ‘interactiveness’. If the facilitator would like to emphasis the societal concepts during the mapping exercise (IOS model) in group work, some modification is needed. It will be further discussed in the theories session of the next chapter.

7.6 Limitations and directions for future research

This study involved three main datasets. First, the theoretical framework for prototyping analysis and method evaluation. Second, the case studies of participatory design/co-creation workshops in which I participated. Third, the design workshop (AEIOU design task) led by me for the investigation of ‘prototype-ability’. Various limitations and recommendations for future studies are discussed below.

7.6.1 Case studies

The 12 case studies of participatory design/co-creation workshops showed diverse types of workshops. I was involved either as a planner, facilitator or participant. Therefore, the workshops I organised and planned may show personal biases. For example, I may make more insightful comments (e.g. positive impression) about the workshops I know well, while unfamiliar workshops may receive less important comments.

The cases chosen were local projects, raising some concerns. They only reflected part of the situation in Hong Kong. As most cases were unique, the processes were similar, such as the tools and methods used. But the contexts were very different. For instance, some local social innovation organisations implemented participatory design projects over the last two years, exploring new topics on redefining specific public spaces, such as public park, public library and wet market.

The participants’ profile (age, gender and education) and the research contexts varied for most participatory design workshops with open recruitment. In fact, it was difficult to manage the group dynamics and participation of the workshop participants. For instance, the facilitators used different skills in their coaching. However, it will be necessary to collect more cases if the data are to be generalised.

7.6.2 The design task

The participants were relatively young and well educated. However, this does not represent the situation of other types of participatory design workshops with older people or people without modern academic training. For instance, I offered a workshop for 30 staff working in a nursing home. Some entry level staff (such as cleaning workers) were not familiar with Post-it notes and did not feel comfortable writing. They were reluctant to participate in the workshop until my team provided images/photos and maps to facilitate the brainstorming activities.

The topic of the design task was ‘intergenerational interaction in a park’. The key concept, ‘intergenerational’, was an abstract concept, which could be challenging for the participants who were not familiar with idea brainstorming. This may have affected their involvement in the exercise. From my observations, 10% to 15% of the workshop participants did not focus on the design task, thus the results may not reflect the actual capacity of the informants.

Language is always a problem space in the facilitation of design workshops. The AEIOU exploration required massive and quick verbal inputs, although I also reminded the participants that they could draw. The oral articulation of the participants was an issue. **Verbal articulation** (reading and writing) also affected accuracy to measure the performance of the participants. In addition, time constraints affected the results, especially for those who were not sensitive to verbal language. Moreover, although the **visual representation** was encouraged during the design task, few participants used sketches in the AEIOU exercise.

The background provided for the scenario drawing worked well. It was observed that some participants could identify the elements of the environment and adapt their concept to it. However, some participants were unable to use the scale and perspective of the background images, suggesting that additional instructions may be needed.

7.6.3 The coding problem

The coding was done by one person (me). Therefore, the interpretation of the data may have fluctuated or been biased, even though I referred to coding guidelines. If additional human resources are provided, the data should be analysed by at least two or three experienced researchers using the same coding scheme, and the analysis should be compared and validated during the analytical and conclusion process.

There are many ways to cluster concepts (data). It is not easy to conduct an exhaustive exploration of different clustering approaches. It also takes several iterative steps to refine or modify the code descriptions.

7.6.4 IOS enabling model

With respect to how knowledge or a concept is mentally represented in the human mind, different models were introduced. The dual coding theory (Paivio, 1986) explains how verbal and visual elements are transformed into symbolic representations. There is an alternative to dual coding, called the propositional theory, which states that mental representation deals with the relationships between things around us and shapes our knowledge. In addition, creating propositions about the relationships between the concepts of things is the way people perceive the concepts. However, dual coding clearly differentiates verbal and visual inputs, which are the two main sensory materials generated during most design workshops. The explanation supports the argument of this research that collaborative prototyping depends on the effectiveness of communication- what and how the participants express their ideas verbally and visually. This concept is the fundamental input of the **IOS enabling model** proposed by the thesis in which the study showed that the imageability of a design concept (either in word or sketch format) is **directly proportional** to the effective development of a prototype. **Higher the imageability, richer the concreteness** of an early phase design concept can induce a more detailed tangible prototype in next stage of design process.

7.6.5 Prototyping in social innovation process

One of the major limitations of the IOS enabling model is the lacking of concern or clear representation in societal concepts/ information as mentioned in Chapter 7.5.1. To achieving the collaborative encounters in design process with the stakeholders, studying the goals of **prototyping in social innovation** context cannot ignore the **sociality** (e.g. symbolic meaning to and ideology of the people in a city) in the

materiality of the design (e.g. the affordance of physical structure of a product and used technologies to the user and group of people). For instance, an outdoor bench with a mobile phone charging feature powered by solar energy can attract users and supports social goals such as encouraging people to put down the phone for wireless charging and enabling socialization. This concept involves a group of stakeholders, including the bench's users, government, and technical staff, to maintain the system. If we analysis this network (the service system facilitated by the new bench) through an organisation point of view, a theory from organisational studies called **sociomateriality** (Orlikowski, 2007; Orlikowski & Scott, 2008; Leonardi et al., 2012) can contribute to the understanding of the phenomenon on how the material (e.g. the technology or interactive prototype) affects the user's behaviour, decision making and or the quality of interaction of the community. In the lens of sociomateriality, social innovation projects explore, engage, and challenge organisational problems, in particular, the projects involving government, public assets, administration problems, community design or related service system etc.

In the theory of sociomateriality, Orlikowski (2007) proposed the concept of **constitutive entanglement**. The notion of this concept recognizes that there are no existing independent entities with inherent characteristics, and the entities should be in a relationship that entails or enacts each other in the daily practice. The entanglement is constructed by the **'socio' (sociality)** and the **'materiality' (materiality)**. Sociality includes, but not limited to, the cultural, institutional, and situated aspects of the organisation of human activities. Materiality includes, but not limited to, the material artifacts, technologies, bodies, arrangements, and infrastructures whereby the human act and interact are performed. It is also worth to note that technology is viewed as a socially recognizable format (including both software and hardware) that is a combination of material artefacts and social impact. It mostly refers to three different contexts or combination of the three including a tool (or machine), a technique or the cultural force ranging from the tangible material objects used by a human (such as machine, hardware or utensils) to the intangible themes including systems, methods of organisation and techniques. Thus, the integration of sociomateriality into the IOS enabling model can better address the emerging direction of social innovation projects in particular for those incorporating new technologies into the conventional social service system.

In the perspective of facilitating the co-creation process effectively, I argue that it is necessary to **differentiate between the general prototyping activities and the prototyping activities with social missions**. As the definition mentioned earlier, in general, a prototype is a simplification of a product concept and technique intended to solve product development problems and to facilitate decision-making occurs while a physical object is building and encouraging the generation of new ideas (Otto & Wood, 2001; Dam & Siang, 2019). This emphasis mainly aims to elicit the solutions or ideas to the making of the physical design from the participants. On the other hand, as Hartmann and Murray's works emphasised, a prototype functions as a working model (incomplete idea) of a product or service concept for collaborative innovation to provoke and evaluate potential stakeholders (Hartmann et al., 2006; Murray et al., 2010). Hillgren et al. (2011) also elaborated that the prototyping methods can enable open discussion, understand conflict and develop empathy, understand and respect the similarities and differences of others through the collective visualisation and experience before the final implementation. The prototype they define plays a role as the catalyst and binding agent that can enable the above-mentioned objectives with social missions.

These **two emphasises**, not contradictory to each other, are reciprocally constructed of the other or entangled with another. The general prototyping approach stresses the identification of elements and or methods to develop **tangible driven interaction**. It proceeds through the development of concrete experience in which the abstract concept such as intergenerational harmony can be visualized or physicalized. Another one, an agenda on **collaborative encounters** (Manzini, 2015) orientated, places the co-construction, experiment, or empowerment through social-driven tools and methods in the social system as the prior objective, and the tangible and concrete experience comes next. The **intangible form**, a comparatively abstract concept such as the strategies facilitating social value change, including capacities building and empowerment, plays a dominant part in the expected outcomes before the development of or association with the tools and methods.

The term 'prototype' may **limit or confuse** the mental concept of the facilitator and other team members about what types of prototype (or prototyping approaches) are referred. In practice, the facilitator needs a clear guideline or preferably having an explicit term, to the motivation the participants to mentally move from abstract (intangible) to concrete (tangible) and vice versa. For instance, taking the example from the case VI (The Park Lab 2017), if the project team would like to propose the concept of ‘co-management’ of a space in a park (the park users are assumed to get involved to the service design process and daily management of a public space), how the users acceptance/ perception on this concept, involvement of the development of the concept, the conflict between citizens and the park management of the government are foremost important. Thus, the team should pay attention to the discussion and development of, for instance, the strategy to enable the intended social value and method to engage the stakeholders through a prototype rather than focusing on the physical form of the prototype as it will be settled right after having the assumption of the engagement’s strategy or approach to interweaving all the agents and factors.

Thus, in the practice of facilitating the co-creation workshop, the terminology of ‘prototype’ cannot satisfy the **operational need** while guiding the designers or participants to explore concepts on promoting the social interaction, examining specific human actions to address new social value. The association of ‘prototype’ may be confined to signifying the matters related to physical model making and the properties or relationship of the materiality and the functions for the users. Besides, many social innovation concepts embroil in organisation design or related problems such as the practices in the workplace or public service system involving the local community, the service provider, and the government. The concept sociomateriality in organisational theory can extend and refine the IOS enabling model to support the perspective of both social (sociality) and prototyping (materiality) related concepts.

It is also sensible to have a word to describe this specific social-driven prototyping activities. In terms of a noun, I suggest the word **‘socio-prototype’,** which is a subordinate concept under sociomateriality, provides descriptions of the concept about the artefact or activity emphasising the collaborative design, engagement, research along with the co-construction of societally driven design hypothesis that elicits concrete experience, scaffold mutual understanding, and prototypes for social value change. Used as a verb, the ‘socio-prototype’ describes the action that **bridging ‘sociality’** (e.g. belonging to the society) and **‘materiality’** (e.g. the infrastructure or facility in a community enabling social interactions).

Furthermore, it is useful to implement the concept of **constitutive entanglement of the social and material in the design scenario** into the IOS enabling model so that the model can support the development of prototype to articulate the design actions on social aspects, for instance, the participatory design action to the effective functioning of a society in the perspective of **bonding social capital** and **bridging social capital** (Putnam, 2000). The theory of socio-prototype and the IOS model contribute to the principle of co-creation. The clearer distinction on prototyping approaches (the standard vs. socio-) and the emphasis on the concreteness of early phase product design concept can support the facilitator to ensure the **'socio' driven prototype-ability in the co-creation process**.

7.6.5 Future work

Holistic brainstorming/asset/concept mapping approaches, for instance, AEIOU, POEMS, VIPIS, and 6Ws, can help workshop participants explore observable concepts and personal experiences in a comprehensive framework. However, these tools cannot guarantee effective exploration to address a particular strategy or value proposition such as societal value. It is also more challenging if the workshop duration is short. As a planner and participant in numerous workshops exploring innovative concepts to solve problems or improve people's lives (indoor and outdoor), I realised that there are one common disadvantage in implementing a standard design thinking process and using standard tools in different contexts (e.g. using Post-it notes to collect and map all participants' inputs) or general concept mapping tools (such as AEIOU). In practice, workshop participants may spend most of their time mapping the elements and may focus only on the general picture of the context or generic problems. Strategically, standard tools may not **allow the participants to systematically discuss, reflect or explore a specific strategy or value** in terms of (i) the mission or vision of the client (e.g. NGOs/service providers); (ii) specific research questions or problems (e.g. improving the quality of life at home); and (iii) aspects from a specific perspective (e.g. address a theory). More specific mapping tools or brainstorming methods are needed to push forward the prototyping process. Tools or methods to help participants articulate and differentiate abstract and concrete design concepts are also needed. If a large number of concepts (e.g. intergenerational living) and sub-concepts (e.g. elders playing with kids) are collected, the facilitator can mobilise the participants with clearer instructions. Extensive case studies on the connection of conceptual words can be enhanced by the big data approach, and a computer can help solve more complex scenarios in the near future.

Appendices

Appendix A: Design task worksheets

A.1 Task A – Personal data sheet

A

Personal Data Sheet

Project: Design abilities in idea generation and prototyping process

Remark: The data you provided may be used for academic study and dissemination, and be treated anonymously. If you don't agree to release your data, you

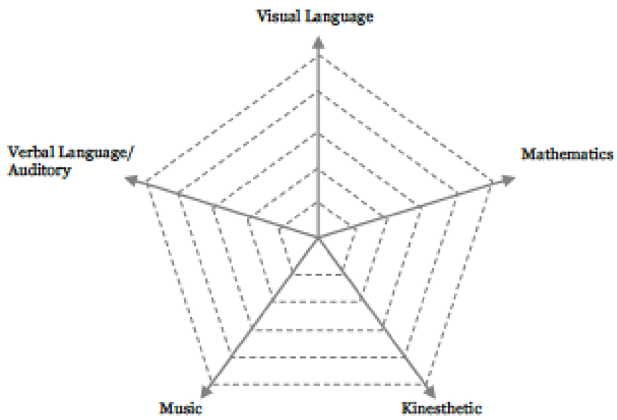
Section I- Self evaluation. Please give yourself a moment to reflect upon the followings:

1. Abilities preferences

(Use "•" to indicate the level as appropriate)

Descriptors:

- **Visual language** - higher rating if you are good at visual memory, comfortable with think and solve ideas visually.
- **Mathematics** - higher rating if you are comfortable & strong in mathematical thinking.
- **Kinesthetic** - higher rating if you are good at thinking through making physical model by hands.
- **Music** - higher rating if you are sensitive and good at musical thinking.
- **Verbal language** - higher rating if you are good at verbal memory, & comfortable with think and solve ideas verbally.



2. Personal information: (may put a "✓" in the box. ☐)

2.1 Age range:
☐ 15 to 20 ; ☐ 21 to 25 ; ☐ 26 to 30 ; ☐ 31 to 35 ; ☐ 36 to 40 ; ☐ 41 to 50 ; ☐ 51 to 60

2.2 Education level:

☐ HD or Asso Degree	(discipline:____________________; years of study (if applicable): ________)
☐ BA/ BEng	(discipline:____________________; years of study (if applicable): ________)
☐ Master or above	(discipline:____________________; years of study (if applicable): ________)

3. Experience	
3.1 Had you participated any design workshop out of design class? Your roles?	☐ Yes; ☐ No Roles: ☐ participant; ☐ facilitator; ☐ coordinator; ☐ others____________
3.2 During meeting or seminar, how often you make notes with verbal language in majority of your time?	☐ below 10%; ☐ 10-25%; ☐ 26-50%; ☐ 51-75%; ☐ 76-90%; ☐ above 90%
3.3 Do you enjoy illustration (sketching or graphical representation)?	☐ Strongly disagree; ☐ Disagree; ☐ Average; ☐ Agree; ☐ Strongly agree
3.4 Do you enjoy handicrafts or making things?	☐ Strongly disagree; ☐ Disagree; ☐ Average; ☐ Agree; ☐ Strongly agree
3.5 In group work, your roles usually are? (please mark 1,2,3...to indicate the roles that usually shows your strength & contribution the most)	☐ Notes taking; ☐ Raising/ articulating concept in verb; ☐ Raising/ articulating concept by drawing; ☐ Verbal data analysis; ☐ Visual data analysis; ☐ Visualization of the concept; ☐ Model making; ☐ Report writing

A.2 Task B1 – Idea brainstorming I

B

Task: Idea brainstorming (I)
活動: 概念開發 (I)

Name: ______________
Date: ______________

Theme: **Inter-generational harmony park 跨代共融公園** | Instruction: Please refer to below AEIOU items and brianstorm ideas as many as possible that fulfils the theme. Please fill in the three columns in white with **text-only descriptions within 15 mins.**

Activities 活動	Environment 環境	Interaction 互動	Objects 物件	Users 用家
Inter-generational harmony or ... 跨代共融活動 或其它...	Public space 公共空間	Playful experience or ... 玩樂體驗 或其它...	Public facilities or ...(existing or new) 公園設施 或其它...(現有或全新的)	Adult & younger people 成人, 少年人/ 小孩

v2

Prepared by Brian Lee, School of Design, The HKPolyU@2018

A.3 Task B2 – Idea brainstorming II

B

Task: Idea brainstorming (IIa)
活動: 概念開發 (IIa)

Name: ______________
Date: ______________

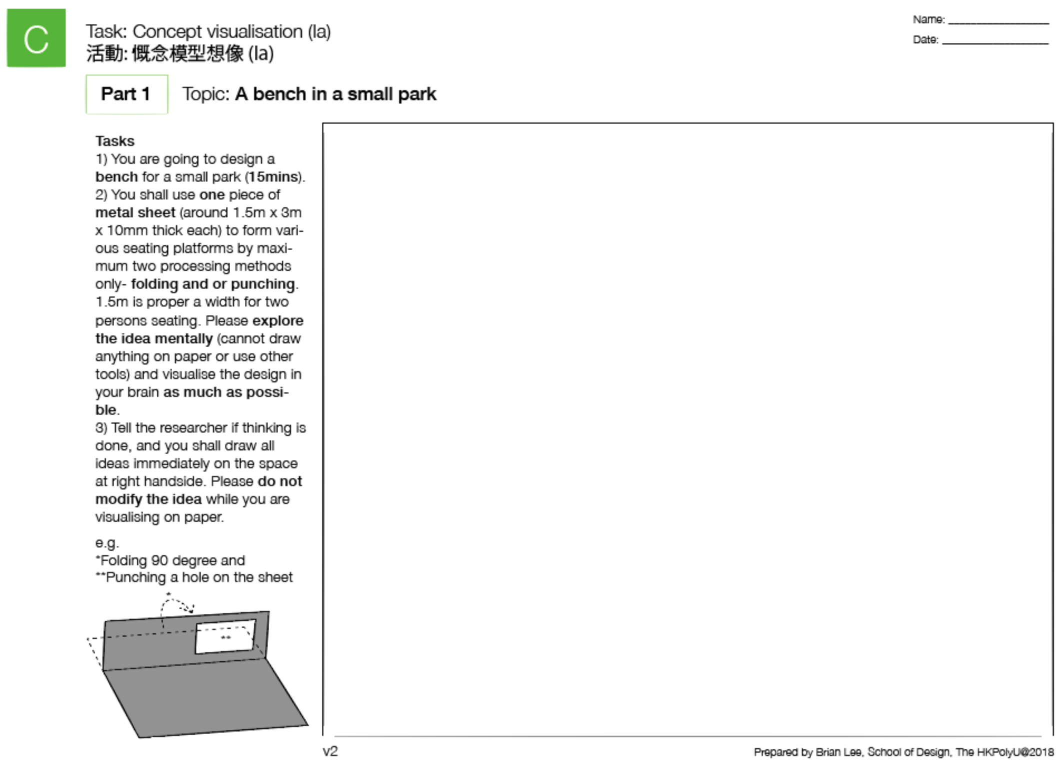
Theme: **Inter-generational harmony park 跨代共融公園** | Instruction: Please refer to below AEIOU items and brianstorm ideas within the following suggested scope under the same theme as many as possible. Please fill in the three columns in white with **text & sketch within 15 mins**, and **illustrate one of appropriate concept** at another page (**2 mins**).

Activities 活動	Environment 環境	Interaction 互動	Objects 物件	Users 用家
Inter-generational harmony or ... 跨代共融活動 或其它...	Public space 公共空間	Playful experience or ... 玩樂體驗 或其它...	Public facilities or ...(existing or new) 公園設施 或其它...(現有或全新的)	Adult & younger people 成人, 少年人/ 小孩
Inter-generational exploration in nature 長幼一同體驗大自然	Park with trees, birds & insects 公園之樹花鳥蟲魚	Learning about nature through see & touch 自然生物接觸及玩樂經驗	Exploration tools or facilities 探索工具或設施	Elderly & children/ grand kids 祖父母及孫兒

v2

Prepared by Brian Lee, School of Design, The HKPolyU@2018

A.4 Task C1 – Concept visualisation Ia (spatial ability)



C

Task: Concept visualisation (Ia)
活動: 概念模型想像 (Ia)

Name: ______________
Date: ______________

Part 1 Topic: **A bench in a small park**

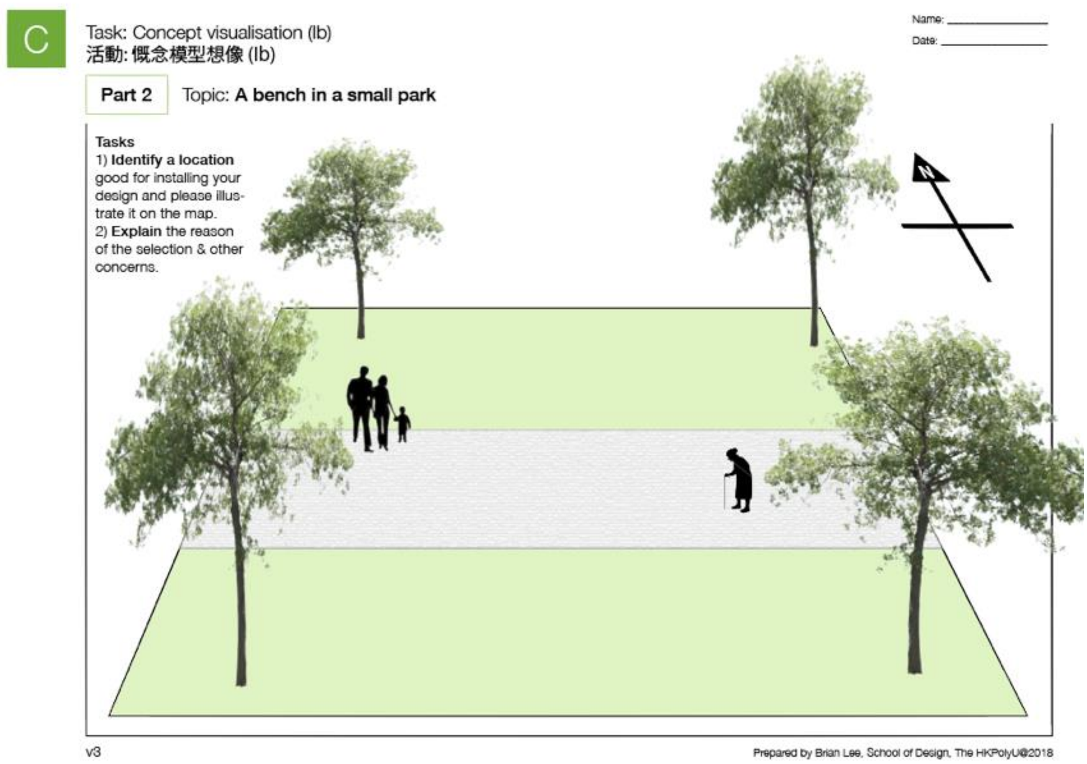
Tasks
1) You are going to design a **bench** for a small park (**15mins**).
2) You shall use **one** piece of **metal sheet** (around 1.5m x 3m x 10mm thick each) to form various seating platforms by maximum two processing methods only- **folding and or punching**. 1.5m is proper a width for two persons seating. Please **explore the idea mentally** (cannot draw anything on paper or use other tools) and visualise the design in your brain **as much as possible**.
3) Tell the researcher if thinking is done, and you shall draw all ideas immediately on the space at right handside. Please **do not modify the idea** while you are visualising on paper.

e.g.
*Folding 90 degree and
**Punching a hole on the sheet

v2

Prepared by Brian Lee, School of Design, The HKPolyU@2018

A.5 Task C2 – Concept visualisation Ib (scenario design)



C

Task: Concept visualisation (Ib)
活動: 概念模型想像 (Ib)

Name: ______________
Date: ______________

Part 2 Topic: **A bench in a small park**

Tasks
1) **Identify a location** good for installing your design and please illustrate it on the map.
2) **Explain** the reason of the selection & other concerns.

v3

Prepared by Brian Lee, School of Design, The HKPolyU@2018

Appendix B: Data coding card

B.1 Data input and coding card

This form was used to record the analysis (descriptions, grading and coding scheme) of the 58 design task results.

Data input & coding card

Data input date:

<table>
<tr><td>Case no</td><td></td><td>Informant name</td><td></td><td>Education background</td><td></td><td colspan="2">Age range</td><td colspan="2"></td></tr>
<tr><td colspan="2" rowspan="2">Self-evaluated cognitive thinking preferences</td><td rowspan="2">Verbal:</td><td rowspan="2">Visual:</td><td rowspan="2">IOS Score</td><td rowspan="2"></td><td>I</td><td>O</td><td>S</td><td>=</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="6">General comment</td><td colspan="4">Coding</td></tr>
<tr><td colspan="6"></td><td colspan="4"></td></tr>
</table>

B.2 Overview of the coding results of the 58 design workshop participants

Sample No	Coding General comment to the AEIOU & scenario prototype	Descriptions about enhancement of prototyping	Discipline	AEIOU Verbal means dominant / verbal driven	AEIOU concepts work worth with the sketch	Low concreteness AEIOU (e.g. abstract 'interaction')	AEIOU not strongly connect to sketch	No connection between verbal and visual	Very few AEIOU are transferred into visual	Sensitive verbal concept on the topic	Lack of information on user experience e.g. seating, playing	Sketch / objectness Visual means dominant/ visual driven	Good sketch with detailed considerations	Good sketch but not connect to the theme	Very weak scenario sketch (cannot communicate)	Sketching is better than verbal	Rate high visual but weak in sketching	Sketching stimulates new concept or detailed thoughts	Interactiveness Weak 'interaction ' concept	Interaction' is essential to overall design	Situatedness Situatedness ' contributes the critical part
1	Very successful scenario (clear & simple); With empathy & holistic strategy; Though abstract verb, but sketch performs well to have detailed thoughts		Law&Business		1	1				1			1					1			
2	Lack of AEIOU; Fail to connect with the sketch; Lack of concreteness & situatedness;		Nursing			1									1						
3	Lack of AEIOU; Very weak sketch & scale is not correct; no connection with visual & verbal; Two items in 'interaction' contributes to the design		Fasion Design/Management												1					1	
5	Lanscape orientation is considered; AEIOU doesn't connect with drawing		Social work				1														1
6	Rate himself 5 at visual but his sketch is very primitive; Only one item ('interaction') contribute to concept sketch.		Finacne												1		1			1	
7	One of the best detailed sketches; All round consideration; Not very creative; 'Interaction' well connect with the sketch/ scenario;		MBA									1	1							1	
8	One of the best visualizer; Few AEIOU items relate to the sketch; 'Think through drawing';		Furniture design				1					1	1					1			
9	Good sketch concept but doesn't connect with AEIOU;		Interactive media				1					1	1								
10			LSGI					1							1						
11	Sketch shows more varities & detail than verbal concept.		Interactive media									1				1					
12	Interaction' works well to sitimulate the concept;		Management Science																	1	
13	Abstract AEIOU; sketch supports more concrete concept		Unspecified			1						1						1			
14	Only one 'interaction' item that is 'competition'; weak 'interaction' leads to weak design		MLS	1		1													1		
15	Abstract 'interaction'; object not connects to 'interaction' concept		Medical Laboratory Science			1	1	1							1						
16	Weak visualization; verbal thinking plays dominant role;		Product Engineerin	1		1									1						
17	Abstract AEIOU; not connec to sketch;		E-Commerce			1		1													
18	Very not clear sketch; abstract 'interaction'		Unspecified			1									1						
19	2D layout plan only; only 2 items out of 20 are partially related to the design; weak in describing seting experience		Art&Design Education			1					1				1				1		
20	AEIOU didn't match the design but the visual is developed; visual enhances her comprehension (dual coding theory)		Law	1		1									1			1			
21	Lack of AEIOU; weak final outcome/ weak sketch		Accountancy			1									1						
22	No data in AEIOU; Weak in both verbal & visual		Management			1									1						
23	Produce various AEIOU items but doesn't connet to sketch; two out of five 'interaction' are abstract;		History	1		1		1							1						
24	Clear 3D drawings but can't answer the theme; the high concret 'object' and 'intera	More concrete 'object' aligning the same 'interacion' concept will make positi	Surveying											1							
25	Weak visualisation;	Some people may make final design design based on what they can produce	Surveying												1						
26	Weak AEIOU relates to sketch; Only two abstract 'object' words are relevant; No de	Weak 'object' also causes weak sketch!?	Fashion Design			1	1								1						
27	Very small AEIOU items; Noe of them relates to sketch; Very weak sketch and no d	Rate himself visual 4 but very low sketch quality.	Computing					1							1						
28	Abstract 'interaction' such as 'play together' and 'without age limit' are stated in AEIOU; no clear connection to sketch.		Computer Science			1		1													
29	Drawing supposrts concept generation	Sketching as approach for generating preferrable idea.	Accounting									1						1			
30	No connection bewteen AEIOU & sketch; weak 'interaction'		Fashion Design					1											1		
31	Able to image a sea; very abstract AEIOU but with detailed sketch;		Computing			1															1
32	No AEIOU connects with sketch; limited verbal concepts; weak 'interaction' description		Information insecurity				1								1				1		
33	Produce many 'interactions' concepts; Drawing is not clear mise lots of visual infor	Could be because he has lots of concrete 'interactions' descriptors, he can rea	Applied Psychology	1											1					1	
34	The verb 'sand' in AEIOU is abstract but it supports strong visual development; Sen	Sketching supports more appropriate concepts such as 'monitoring' and 'chatt	Unspecified			1					1	1				1		1			
35	Only 'activities' concepts are more concrete, thus it could be why it become the do	More concrete 'activities' also contribute to the prototyping / sketching.	Social Science	1	1																
36	No concept relates to 'situation'; 'interaction' is sources of the design; the tactile id	Interaction' contributes to the design; sketch may be affected by the backgrou	Internet and Multimedia Technology									1						1		1	1
37	playful experience' could be eaiser to be represented by verbs rather than drawing;	Play experience' in 'interaction' is relatively abstract, and it is easy to be desc	Computing			1															
38	No verbal description marked on sketch; partial AEIOU connect with sketch; weak sketching		IS									1			1						
39	A object 'white board' is illustrated but didn't further explian how and what are the	The reflection is that if people is lack of concrete experience, they cannot eve	Computing	1		1					1										
40	Lack of AEIOU; only the actitivity 'chess' is mentioned; not creative solution and che	Current design is not clear on addressing quality of ecperience of elderly. Con	Advertising			1					1										
41	Weak concrete description of 'interaction'; no concept breakthrough;		BBA			1															
42	No connection to intergeneration; Weak AEIOU on connecting human experience; No product functional descriptions		Information security			1									1						
43	Only a concept 'dialogue' from AEIOU is adopted in the scenario; very wek skecth but rate visual 4.		Knitwear design						1						1						
44	Some principles are suggested such as "destinction elements are added to create f	Destinctive elements are added to create fun to children'....what is the excat	Finance			1		1							1				1		
45	Detailed described user interaction (e.g. conversation with idea echange amongst	Detailed 'interaction' but not connecting with 'object'. It could be the reason	Finance	1		1															
46	Verbal 'interaction' items are not connected with the scenario sketch; A concept 'li	The informant shows a creative concept with high potential; Visualization me	Marketing			1		1													
47	The design doesn't connect with the theme intergeneration.	The theme intergeneration at public park could be too abstract for most peop	MSc(IT)			1		1							1						
48	Abstraction 'interaction' wording; Provide quite a number of AEIOU concepts; The n	Surprise' is a good choice to describe user experience and it seems that 'play'	Law			1						1	1					1			
49	Quite abstract 'interaction' ('sharing' and 'chatting') and the visualisation with no s	Typical abstract verbal concept and weak sketch.	Social Policy and Administration			1									1						
50	Very abstract 'interaction' words and very weak scenario. The abstract AEIOU conc	This is a good example to look into what means a weak AEIOU verbal explora	Social Policy and Administration			1									1				1		
51	Abstract 'interaction' word 'talking' is adopted into the design but the scenario sket	Typcial abstract verbal concept and weak scenario sketch.	Management			1															
52	Very abstract 'interaction' descriptions and the scenario sketches show many desig	The sketches of the objects cannot show the exact experience or novelty.	Art			1	1														
53	Good descriptions of the specifications; many standalone concept sketches are pro	Is it because the informant is not student and could be a practicing manager i	Engineer managem	1		1	1												1		
54	The informant wrote about principles (or condictions on the sketch) that supports h	Same as sample N53, she is not a student (in civic engineering) and suggeste	Civic	1							1								1		
55	The informant decribes the principles or conditions but didn't able to illustrate it cl	From the review of this case, principle or condition (verbal description) usuall	Education	1											1				1		
56	The wheel chair concept provides a meangingful experience to younger visitor of th	It is worth to learn from this case that even though a sketch is made and it ca	Computing engineering												1						
57	The sketch illustrates with specific situation and arrangement of the objects; Chess	The design is 3 dimensionally drafted and it may help the informant to explor	Unspecified															1			1
58	learning actvities are focused such as 'classroom in the park'. It's a clear concept b	This case shows high potential to developn appropriate concept based on his	Art	1						1										1	
59	Main design strategy 'solving problem together' is developed and a giant puzzle is	It is problematic if the sketch cannot provide enough information. From the a	Unspecified									1			1						

References

Ackermann, E. (2001). Piaget's constructivism, Papert's constructionism: What's the difference? *Future of Learning Group Publication*, *5*(3), 438.

Ackermann, E. (2012). Perspective-taking and object construction: Two keys to learning. (pp. 39-50). In Kafai & Resnick, *Constructionism in practice: Designing, thinking, and learning in a digital world*. France: Routledge.

Adams, R. S., Daly, S., Mann, L. L., & Dall'Alba, G. (2011). Being a professional: Three lenses on design thinking, acting, and being. *Design Studies*, *32*, 598-607.

Ahmed, S., Wallace, K. M., & Blessing, L. T. (2003). Understanding the differences between how novice and experienced designers approach design tasks. *Research in Engineering Design*, *14*(1), 1-11.

Alexander, C. (1964). *Notes on the synthesis of form*. Cambridge, MA: Harvard University Press.

Altheide, D. L. (1996). *Qualitative media analysis*. Thousand Oaks, CA: Sage.

Anderson, L. W., Krathwohl, D. R., & Bloom, B. S. (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. Allyn & Bacon.

Arnheim, R. (1969). *Visual thinking*. Berkeley, CA: University of California Press.

Arnheim, R. (1980). A plea for visual thinking. *Critical Inquiry,* 489-497.

Ashworth, P., & Lucas, U. (1998). What is the "world" of phenomenography? *Scandinavian Journal of Educational Research*, *42*(4), 415-431.

Audi, R. (ed.) (1999). *The Cambridge dictionary of philosophy*. Cambridge, UK: Cambridge University Press.

Barthes, R. (1973). *Elements of semiology* (translated from the French by Annette Lavers and Colin Smith). New York, NY: Hill and Wang (Original work published 1967).

Binder, T., & Brandt, E. (2008). The design: Lab as platform in participatory design research. *Co-Design*, *4*(2), 115-129.

Brandt, E. (2007). How tangible mock-ups support design collaboration. *Journal of Knowledge, Technology & Policy*, *20*(3), 179-192.

Brooks-Harris, J. E., & Stock-Ward, S. R. (1999). *Workshops: Designing and facilitating experiential learning*. Thousand Oaks, CA: Sage Publications.

Brown, T. (2008). Design thinking. *Harvard Business Review*, *86*(6), 84.

Brown, T., & Wyatt, J. (2010). Design thinking for social innovation. *Development Outreach*, *12*(1), 29-43

Bryman, A. (2008). *Social research methods* (5th edition). Oxford, UK: Oxford university press.

Bucciarelli, L. L. (2002). Between thought and object in engineering design. *Design Studies, 23*(3), 219-231.

Buchanan, R. (1992). Wicked problems in design thinking. *Design Issues*, 5-21.

Buchanan, R. (2001). Design research and the new learning. *Design Issues*, *17*(4), 3-23.

Burdick, A. (2009). Design without designers. Paper presented at *Keynote for a Conference on the Future of Art and Design Education in the 21st Century*, University of Brighton, England.

Burns, C., Cottam, H., Vanstone, C., & Winhall, J. (2006). RED paper 02: Transformation design. London: Design Council

Camburn, B. A., Sng, K. H., Perez, K. B., Otto, K., Wood, K. L., Jensen, D., & Crawford, R. (2015). The way makers prototype: Principles of DIY design. In *ASME 2015 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference* (pp. V007T06A004-V007T06A004). American Society of Mechanical Engineers.

Cila, N., Hekkert, P., & Visch, V. (2014). Digging for meaning: The effect of a designer's expertise and intention on depth of product metaphors. *Metaphor and Symbol*, *29*(4), 257-277.

Clark, J. M., & Paivio, A. (1991). Dual coding theory and education. *Educational Psychology Review*, *3*(3), 149-210.

Community Museum Project. (2010). *From trash to treasure: Designing upcycling systems*. Hong Kong, HKSAR: Hong Kong Institute of Contemporary Culture Limited, Asia One Printing.

Crilly, N., Moultrie, J., & Clarkson, P. J. (2009). Shaping things: Intended consumer response and the other determinants of product form. *Design Studies*, *30*(3), 224-254.

Cross, N. (1982). Designerly ways of knowing. *Design Studies*, *3*(4), 221-227.

Cross, N. (1999a). Design research: A disciplined conversation. *Design Issues*, 5-10.

Cross, N. (1999b). Natural intelligence in design. *Design Studies*, *20*(1), 25-39.

Cross, N. (2001a). Designerly ways of knowing: Design discipline versus design science. *Design Issues*, *17*(3), 49-55.

Cross, N. (2001b). Strategic knowledge exercised by outstanding designers. *Strategic Knowledge and Concept Formation III*, 17-30.

Cross, N. (2006). *Designerly ways of knowing*. London, UK: Springer.

Cross, N. (2011). *Design thinking: Understanding how designers think and work.* Oxford, UK, and New York, NY: Berg.

Dalsgaard, P. (2014). Pragmatism and Design Thinking. *International Journal of design*, 8(1).

Dam, R., & Siang, T. (2018). Introduction to the essential ideation techniques which are the heart of design thinking [Blog article]. Retrieved from https://www.interaction-design.org

Danesi, M., & Perron, P. (1999). *Analyzing cultures: An introduction and handbook.* Bloomington, IN: Indiana University Press.

De Bono, E. (2009). *Lateral thinking: A textbook of creativity*. London, UK: Penguin Books UK.

Dearling, A. (1992). *How to organise conferences, workshops, and training events: A guide for trainers and facilitators working in the 'people services'.* Longman.

Demirbilek, O., & Demirkan, H. (2004). Universal product design involving elderly users: A participatory design model. *Applied Ergonomics, 35*(4), 361-370.

Desmet, P. M. A., & Hekkert, P. (2007). Framework of Product Experience. *International Journal of Design*, 1(1), 13-23.

Ehan, P. (1988). *Work-oriented design of computer artifacts.* Falköping, Sweden: Arbetslivcentrum/Almqvist and Wiksell International.

Emspak, F. (1993). Workers, unions, and new technology. In *Participatory design: Principles and practices* (pp. 13-26). Boca Raton, FL: CRC Press.

Ericsson, K. A., & Simon, H. A. (1984). *Protocol analysis*. Cambridge, MA: MIT Press.

Erlhoff, M., & Marshall, T. (2008). *Design dictionary: Perspectives on design terminology*. Basel, Germany: Birkhauser.

Feijs, L. (2013). Product semantics: Quo Vadis. *DeSForM2013*. Retrieved from http://desform2013.id.tue.nl/wp-content/uploads/2013/09/DeSForM2013.pdf

Feijs, L., & Meinel, F. (2005). A formal approach to product semantics with as application to sustainable design. *Design Issues*, *21*(3), 67-81.

Feijs, L., & Meinel, F. (2007). A case study in formal product semantics. *Journal of Design Research*, *6*(4), 462-486.

Ferguson, E. S. (1994). *Engineering and the mind's eye*. Cambridge, MA: MIT Press.

Ferreira, E. C. K. (2013, December 12). Is there any study or development on phenomenology of "designing"? [Online forum question]. Retrieved from https://www.researchgate.net/post/Is_there_any_study_or_development_on_phenomenology_of_designing/1

Galle, P. (2002). Philosophy of design: An editorial introduction. *Design Studies*, *23*(3), 211-218.

Galle, P. (2011). Foundational and instrumental design theory. *Design Issues*, *27*(4), 81-94.

Gardner, H. (2011). *Frames of mind: The theory of multiple intelligences*. New York, NY: Basic Books.

Gero, J. S. (2015). *Studying visual and spatial reasoning for design creativity*. Springer, US.

Gero, J. S., & McNeill, T. (1998). An approach to the analysis of design protocols. *Design Studies*, *19*(1), 21-61.

Goldschmidt, G. (2017). Manual sketching: Why is it still relevant? In *The Active Image* (pp. 77-97). Cham, Switzerland: Springer.

Goldschmidt, G. (2001). Visual analogy—a strategy for design reasoning and learning. In *Design knowing and learning: Cognition in design education* (pp. 199-219). Elsevier Science.

Goldschmidt, G., & Smolkov, M. (2006). Variances in the impact of visual stimuli on design problem solving performance. *Design Studies*, *27*(5), 549-569.

Goulding, C. (2005). Grounded theory, ethnography and phenomenology: A comparative analysis of three qualitative strategies for marketing research. *European journal of Marketing*, *39*(3/4), 294-308.

Greenbaum, J. (1993). A design of one's own: Towards participatory design in the United States. In *Participatory design: Principles and practices* (pp. 27-37). Boca Raton, FL: CRC Press.

Guzdial, M. (2018, March 19). Constructivism vs. constructivism vs. constructionism [Computing education research blog]. Retrieved from https://computinged.wordpress.com/2018/03/19/constructivism-vs-constructivism-vs-constructionism/

Halverson, E. R., & Sheridan, K. (2014). The maker movement in education. *Harvard Educational Review*, *84*(4), 495-504.

Hannah, G. G. (2002). *Elements of design: Rowena Reed Kostellow and the structure of visual relationships.* New York, NY: Princeton Architectural Press.

Hartmann, B., Klemmer, S. R., Bernstein, M., Abdulla, L., Burr, B., Robinson-Mosher, A., & Gee, J. (2006). Reflective physical prototyping through integrated design, test, and analysis. In *Proceedings of the 19th annual ACM symposium on User interface software and technology* (pp. 299-308). ACM.

Hekkert, P. (2006). Design aesthetics: principles of pleasure in design. *Psychology science*, 48(2), 157.

Heron, J. (1985). The role of reflection in a co-operative inquiry. In D. Boud et al., *Reflection: Turning experience into learning*. New York, NY: Nicholas Publishing Co.

Heskett, J. (1980). *Industrial design*. London, UK: Thames and Hudson Ltd.

Hillgren, P. A., Seravalli, A., & Emilson, A. (2011). Prototyping and infrastructuring in design for social innovation. *Co-Design*, *7*(3/4), 169-183.

Ingold, T. (Ed.). (2011). *Redrawing anthropology: Materials, movements, lines*. Farnham, UK: Ashgate Publishing, Ltd.

Johnson-Sheehan, R., & Baehr, C. (2001). Visual-spatial thinking in hypertexts. *Technical Communication*, *48*(1), 22-30.

Jones, J. C. (1992). *Design methods*. Canada: John Wiley & Sons.

Jordan, P. W. (1998). Human factors for pleasure in product use. *Applied Ergonomics*, *29*(1), 25-33.

Jordan, P. W. (2000). *Designing pleasurable products: An introduction to the new human factors.* London, UK, and New York, NY: Taylor & Francis.

Jordan, P. W. (2002). *Designing pleasurable products: An introduction to the new human factors.* Boca Raton, FL: CRC press.

Kasprisin, R. J. (1995). *Visual thinking for architects and designers: Visualizing contents in design.* London, UK, and New York, NY: Van Nostrand Reinhold.

Kim, K. Y., Psenka, C. E., Jackson, K. S., & Haapala, K. R. (2015). Constructionist learning for environmentally responsible product design. In *Proceedings of the 2015 ASEE Annual Conference and Exposition* (pp. 26-398).

Kimbell, L. (2011). Rethinking design thinking: Part I. *Design and Culture, 3*(3), 285-306.

Kress, G. R. (2006). *Reading images: The grammar of visual design*. London, UK, and New York, NY: Routledge.

Krippendorff, K. (1995). On the essential contexts of artifacts or on the proposition that “design is making sense (of things)”. In V. Margolin, & R. Buchanan (Eds.), *The idea of design: A design issues reader* (pp. 156-184). Cambridge, MA: MIT Press.

Krippendorff, K. (2006). *The semantic turn: A new foundation for design*. Boca Raton, FL: CRC Press.

Krippendorff, K., & Butter, R. (2008). *Semantics: Meanings and contexts of artifacts. In Product experience* (pp. 353-376). Elsevier.

Kroes, P. (2002). Design methodology and the nature of technical artefacts. *Design Studies, 23*(3), 287-302.

Kwok, J. Y. C. (2004). The weight of space: Participatory design research for configuring habitable space for new arrival women in Hong Kong. In *Proceedings of the Eighth Conference on Participatory Design: Artful Integration: Interweaving Media, Materials and Practices – Volume 1* (pp. 183-192). ACM.

Laurel, B. (Ed.) (2003). *Design research, methods and perspectives.* Cambridge, MA: MIT Press.

Lawson, B. (2006). *How designers think: The design process demystified*. New York, NY: Princeton Architectural Press.

Lee, B., & Chan, D. (2013). *World of women workers.* Oi! – Oil street art space, art promotion office (Leisure and Cultural Services Department, Hong Kong Government), Hong Kong, 22 May to 30 September 2013.

Leonardi, M.P., Nardi, B.A., & Kallinikos, J. (2012). Materiality, sociomateriality, and socio-technical systems: What do these terms mean? How are they different? Do we need them. *Materiality and organizing: Social interaction in a technological world*, 25. UK: Oxford.

Mabogunje, A., Hansen, P. K., Eris, O., & Leifer, L. (2008). Product Design and Intentional Emergence facilitated by Serious Play. In *DS 50: Proceedings of NordDesign 2008 Conference, Tallinn, Estonia, 21-23 August 2008*.

Manktelow, K. (2012). *Thinking and reasoning: An introduction to the psychology of reason, judgment and decision making*. Psychology Press.

Manzini, E. (2015). *Design, when everybody designs: An introduction to design for social innovation*. MIT press.

Mark Baskinger & Bruce Hanington. (2011) *Drawing Ideas*. Retrieved from http://www.drawingideasbook.com/resources.html

Marton, F. (1981a). Phenomenography – Describing conceptions of the world around us. *Instructional Science, 10*(2), 177-200.

Marton, F. (1981b). Studying conceptions of reality – A metatheoretical note. *Scandinavian Journal of Educational Research, 25,* 159-169.

Marton, F. (1986). Phenomenography – A research approach investigating different understandings of reality. *Journal of Thought, 21,* 28-49.

Marton, F., & Booth, S. (1997). *Learning and awareness*. Mahwah, NJ: Lawrence Erlbaum Associates.

Mathewson, J. H. (1999). Visual-spatial thinking: An aspect of science overlooked by educators. *Science Education*, *83*(1), 33-54.

McKim, R. H. (1972). *Experiences in visual thinking*. Wadsworth Publishing.

Munro, A. J. (2011). Autoethnography as a research method in design research at universities. Paper presented at the *Sixth International DEFSA Conference Proceedings*, *Design Education Forum of Southern Africa*.

Murray, R., Caulier-Grice, J., & Mulgan, G. (2010). *The open book of social innovation*. London, UK: National endowment for science, technology and the art.

Mutlu, B., & Er, A. (2003). Design innovation: Historical and theoretical perspectives on product innovation by design. *The 5th European Academy of Design Conference*. Barcelona.

Norman, D. A. (1993). Cognition in the head and in the world. *Cognitive Science*, *17*, 1-6.

O’Neill, S. (2008). *Interactive media: The semiotics of embodied interaction*. Berlin, Germany: Springer Science & Business Media.

Orlikowski, W. J. (2007). Sociomaterial practices: Exploring technology at work. Organization studies, 28(9), 1435-1448.

Orlikowski, W. J., & Scott, S. V. (2008). 10 sociomateriality: challenging the separation of technology, work and organization. The academy of management annals, 2(1), 433-474.

Osgood, C. (1953). *Method and theory in experimental psychology*. Oxford, UK: Oxford University Press.

Otto, K., & Wood, K. (2001). *Product design: Techniques in reverse engineering and new product development.* Upper Saddle River, NJ: Prentice Hall.

Owen, C. (2007). Design thinking: Notes on its nature and use. *Design Research Quarterly*, *2*(1), 16-27.

Owens, K. (2015). Visuospatial Reasoning in Twentieth Century Psychology-Based Studies. In *Visuospatial Reasoning* (pp. 19-90). Springer, Cham, Switzerland.

Oxman, R. (1997). Design by re-representation: A model of visual reasoning in design. *Design Studies*, *18*(4), 329-347.

Oxman, R. (2002). The thinking eye: visual re-cognition in design emergence. Design Studies, 23(2), 135-164.

Paivio, A. (1971). *Imagery and verbal processes*. New York, NY: Holt, Rinehart and Winston.

Paivio, A. (1986). *Mental representations: A dual coding approach*. New York, NY: Oxford University Press.

Poulsen, S. B., & Thøgersen, U. (2011). Embodied design thinking: A phenomenological perspective. *Co-Design*, *7*(1), 29-44.

Prototype. (n.d.). In *Merriam-Webster's online dictionary*. Retrieved from https://www.merriam-webster.com/dictionary/prototype

Putnam, R. D. (2000). Bowling alone: The collapse and revival of American community. New York, NY: Simon and Schuster.

Razzouk, R., & Shute, V. (2012). What is design thinking and why is it important? *Review of Educational Research*, 0034654312457429.

Rittel, H., & Webber, M. (1973). Dilemmas in a general theory of planning. *Policy Sciences*, *4*, 155-169.

Robinson, R. (2015, February 23). Building a useful research tool: An origin story of AEIOU. *Epic*. Retrieved from https://www.epicpeople.org/building-a-useful-research-tool/

Sanders, E. B. N. (2005). Information, inspiration and co-creation. Paper presented at *The 6th International Conference of the European Academy of Design*, Bremen, Germany.

Sanders, E. B. N., Brandt, E., & Binder, T. (2010, November). A framework for organizing the tools and techniques of participatory design. In *Proceedings of the 11th biennial participatory design conference* (pp. 195-198). ACM.

Sanders, E. B. N., & Stappers, P. J. (2008). Co-creation and the new landscapes of design. *Co-Design*, *4*(1), 5-18.

Sanders, E. B. N., & Stappers, P. J. (2014). Probes, toolkits and prototypes: three approaches to making in codesigning. CoDesign, 10(1), 5-14.

Sarder, B. (2007). *Managing design knowledge: Ontology modeling in product and process design.* Saarbrucken, Germany: AV Akademikerverlag.

Schön, D. (1983). *The reflective practitioner: How professionals think in action*. New York, NY: Basic Books.

Schuler, D., & Namioka, A. (Eds.) (1993). *Participatory design: Principles and practices*. Boca Raton, FL: CRC Press.

Silverman, L. K. (2002). *Upside-down brilliance: The visual-spatial learner*. Deleon Pub.

Simon, H. A. (1996). *The sciences of the artificial* (Vol. 136). Cambridge, MA: MIT press.

Smith, M. K. (2002). Howard Gardner and multiple intelligences. *The Encyclopedia of Informal Education*, *15*, 2012.

Snodgrass, A., & Coyne, R. (1996). Is designing hermeneutical? *Architectural Theory Review*, *2*(1), 65-97.

Sowa, J. (2000). *Knowledge representation, logical, philosophical, and computational foundations.* Retrieved from http://www.jfsowa.com/krbook/

Stake, R. E. (1978). The case study method in social inquiry. *Educational Researcher*, *7*(2), 5-8.

Stake, R. E. (1995). *The art of case study research.* Thousand Oaks, CA: Sage.

Stappers, P. J., & Giaccardi, E. (2017). Research through design. In M. Soegaard, & R. Friis-Dam (Eds.), *The encyclopedia of human-computer interaction* (2nd edition, pp. 1-94). The Interaction Design Foundation.

Steinert, Y., & Ouellet, M. N. (2012). *Designing successful workshops*. Montréal, Canada: McGill University.

Sutton, K., & Williams, A. (2010). Implications of spatial abilities on design thinking. Paper presented at *Design & Complexity. Design Research Society, Montreal (Quebec), Canada*.

Thagard, P., & Shelley, C. (1997). Abductive reasoning: Logic, visual thinking, and coherence. In *Logic and scientific methods* (pp. 413-427). Springer Netherlands.

Thompson, J. A. A., & Blossom, N. H. (2015). *The handbook of interior design*. John Wiley & Sons, Ltd.

Tiger, L. (1992). *The pursuit of pleasure*. Transaction Publishers.

Tonkinwise, C. (2011). A taste for practices: Unrepressing style in design thinking. *Design Studies*, *32*(6), 533-545.

Viemeister, T. (2002). The elements of design: Rowena Reed Kostellow and the structure of visual relationships, a book by Gail Greet Hannah. *FIDSA, springtime-usa.com*. Retrieved from https://www.idsa.org/sites/default/files/2002_Tucker%20Viemeister.pdf

Walsh, V., Roy, R., Potter, S., & Bruce, M. (1992). *Winning by design: Technology, product design and international competitiveness*. Oxford, UK: Basil Blackwell.

Wang, D. (2015). An overview of phenomenology for the design disciplines. In J. A. A. Thompson, & N. H. Blossom (Eds.), *The handbook of interior design* (p. 11). John Wiley & Sons Ltd, UK.

Wang, D., & Wagner, S. (2007). A map of phenomenology for the design disciplines. *Environmental & Architectural Phenomenology Newsletter*, *18*, 10-15.

Ware, C. (2005). *Knowledge and information visualization* (pp. 27-35). Berlin: Springer Berlin Heidelberg.

Westerlund, B. (2007). A workshop method that involves users talking, doing and making. Paper presented at the *Human Machine Interaction Conference, HuMaN'07*, Timimoun, Algerian Sahara.

Zhukovskiy, V. I., Pivovarov, D. V., Жуковский, В. И., & Пивоваров, Д. В. (2008). The nature of visual thinking. Journal of Siberian Federal University. Humanities & Social Sciences 1 (2008) 149-158.