論文 / 著書情報
Article / Book Information

題目(和文)	
Title(English)	Modeling Interpretation of Structure in Design as a Situated Phenomenon via Observation & Analysis of Design Activity
著者(和文)	カーロン ユバル
Author(English)	Yuval Kahlon
出典(和文)	学位:博士（工学）, 学位授与機関:東京工業大学, 報告番号:甲第11981号, 授与年月日:2021年3月26日, 学位の種別:課程博士, 審査員:藤井 晴行,西條 美紀,齊藤 滋規,野原 佳代子,安田 幸一,大佛 俊泰
Citation(English)	Degree:Doctor (Engineering), Conferring organization: Tokyo Institute of Technology, Report number:甲第11981号, Conferred date:2021/3/26, Degree Type:Course doctor, Examiner:,,,,,
学位種別(和文)	博士論文
Type(English)	Doctoral Thesis

Modeling Interpretation of Structure in Design as a Situated Phenomenon via Observation & Analysis of Design Activity

by

Kahlon Yuval

A Doctoral Thesis

Submitted to

the Graduate School of the Tokyo Institute of Technology

on November 30th

In Partial Fulfilment of the Requirements

for the Degree of Doctor of Engineering

Supervisor: Fujii Haruyuki

Professor of Architecture & Design Science

"As soon as you see something, you already start to intellectualize it. As soon as you intellectualize something, it is no longer what you saw."

-Shunryu Suzuki.[1]

[1] In (Chadwick, 1999).

Committee Members

Tokyo Institute of Technology, School of Environment and Society.

Prof. Nohara Kayoko;

Prof. Osaragi Toshihiro;

Prof. Saijo Miki;

Prof. Saito Shigeki;

Prof. Yasuda Koichi;

Prof. Fujii Haruyuki (supervisor).

Acknowledgements

How do projects come into being? About 14 years ago I have picked up a book about Japanese gardens at a local book store in my home town, Kfar Saba. The photos in the book struck me as magical. Looking back, without realizing it, I always had a strong liking for landscape design, and an interest in the creation of worlds. My attraction to these gardens is thus not surprising.

Towards my graduation with a B.Des, I have found myself absorbed in both learning and teaching computational design. As a person with a great passion for learning, it seemed natural to continue my education to a graduate level, and the idea of combining my two interests occurred to me. I asked myself – can we make a computational system for landscape design? One day, when inquiring about possible educational institutions, I remember my wife saying – 'you like Japanese gardens, why don't you do that in Japan?' The decision to come to Japan had set the grounds for this project, which I am proud of. It seems difficult to thank all of the people that contributed to the work. Nonetheless, one should at least try.

First, I cannot begin to express my gratitude to my supervisor, Professor Fujii Haruyuki, who has taught me more than I could ask for. The patience and passion with which he helped me throughout the project, and his ability to understand his students' needs, cannot be overstated. This project would have never been possible without these.

Also, I owe more than I can repay for my wonderful wife Karina K., who had supported me through each and every step of this long journey. Her insights never cease to surprise me, and our conversations are a major source of inspiration.

In addition, I extend my gratitude to the following people, for our stimulating discussions: Jacob B.Z, Michael S., Barbara R., Prof. John S.; I thank my family and friends, for their continuous and invaluable support. For my mother, Michal. A, who helped my believe in myself, and for my father Clement K., who encouraged me through difficult times.

I would also like to acknowledge the help of the teachers at the graduate school, as their useful advice greatly helped in improving the work. The designers who contributed their time and joined our experiments are much appreciated as well. Finally, I thank the Japanese government and the MEXT program, who had provided me with the opportunity to study and do research in Japan, at the Tokyo Institute of Technology.

Yuval. K

Summary

This thesis deals with the challenge of constructing a thought-framework for systematically describing interpretation activity in design. Such a description can facilitate the future implementation of highly-adaptive human capabilities in digital design support systems.

Chapter 1 introduces the general topic of interpretation, and points out potential pitfalls in its study. Following this, we focus our inquiry on an important interpretive ability, commonly referred to as "seeing as" (which facilitates dynamic changes in perspective, as a response to changing situations). We then state our research aims, and formulate our research question accordingly. The boundaries for our inquiry are set, and our research question is decomposed into four sub-questions, each addressed in a separate chapter of this work (chapters 4-7).

In Chapter 2 we lay out the theoretical background for the work, by introducing key concepts from various fields and disciplines. First, we provide an overview of interpretation in design. Second, we discuss the approach of situated cognition and its effectiveness in studying thinking and action. Third, we touch upon key concepts in knowledge representation and reasoning, which we see as essential for understanding interpretation activity. Fourth, we provide an overview of artificial intelligence approaches to computational design, and review representative examples of computational design systems from each. Fifth, we discuss key notions in semiotics and linguistics, in order to build a firm foundation for analyzing interpretive acts. We then conclude this chapter with an introduction of traditional Japanese rock garden design (JRGD), which we have embraced as a case study in this work.

Chapter 3 presents our methodological approach, which sets one foot in computational design (chapters 4-5), and another in observation of design activity (chapters 6-7). In this, we introduce and justify our choice of JRGs as a case study for the work, as well as our design task (for observing interpretation activity), which was devised in this context.

In Chapter 4 we lay the theoretical foundations for systematically dealing with interpretation, by identifying key entities which lie at its core. We review the practice of interpretation in traditional JRGD, and formulate a computational framework for relating objects with interpretations. The framework is implemented and tested in a Computer-aided Design (CAD) environment, by attempting to generate spatial designs based on interpretive descriptions.

Chapter 5 furthers our efforts by proposing a formal framework for representing and storing interpretations within a database. The framework is implemented via integrating a CAD environment with a logical inference system, and tested by matching stored interpretations with spatial designs.

Chapter 6 turns to design observation, to enrich our understanding of interpretation on the basis of empirical data. We devise, execute and analyze a design task in the context of JRGs, and draw insights regarding how subjects engage in interpretation. We then propose a framework for modeling interpretation in design, which enables to trace the assignment of interpretations in action.

In Chapter 7 we revise and repeat our design task, in attempt to deepen our understanding of human interpretive practices. We suggest how interpretation activity may be understood through a new notion termed "narrative worlds", which frames our various insights so far. This notion, which draws on theories in design cognition, discourse analysis and the philosophy of mind, enables to visualize and understand processes of interpretation through the eyes of the designer.

Chapter 8 discusses the main result of this work - a conceptual framework for systematically inquiring into this activity. In this, we clarify our contribution and position it within state-of-the-art models for computational design. Various implications for design theory and practice, as well as for knowledge engineering and artificial intelligence, are suggested. In addition, we specifically relate our findings with JRGs, which both inspired and enabled this project. We then discuss the main limitations of the work, and suggest possible ways in which these may be addressed.

Finally, Chapter 9 discusses future directions for research, on the basis of the current limitations and by considering our research goals, and concludes this dissertation.

Table of Contents

List of Figures and Tables

Preliminary Terms and Definitions

We provide general definitions for key terms which frequently appear throughout the work. In cases of difference in usage or deviation from these, more specific definitions are provided within each chapter, as needed.

Term	Definition
Structure	Refers to the physical parts which make the artifact that is being designed, or their representation.[2]
Design Space	A physical space which serves as the "site" for our design task; determined by a wooden tray covered by a bed of white sand; identical in all design sessions.
Element	A single indivisible physical part of the design, or its representation.[3]
Representational Interpretation (RI)	Refers to the assignment of a symbolic description to the structure or one of its parts (interpreted object), denoting a set of referents that the interpreted object stands for. As an example, imagine a situation where several architects are discussing the design of a building in front of a scaled model, in which high-rise buildings are represented by small boxes. Under these circumstances, each box is interpreted as a building.
State	A segment of the design session after which change is observed
Agent	Refers to the human individual who is engaging in design activity; notice difference with "artificial agent" below.
Artificial Agent	Refers to a computational system engaging in design.
Conceptual Design	The part of a design process during which the project is conceptually framed by the agent. This is often done by defining a theme to be shared by the various constituents of the design.
Japanese rock Garden Design (JRGD)	The traditional practice of landscape design which consists of placing large rocks on a bed of sand.[4]

[2] corresponds with the definition in (Gero, 1990), stating that these parts and their relations compose "the syntax of a design".
[3] similar to "primitive element" in (Qian & Gero, 1996).
[4] known in Japanese as "枯山水" ("karesansui"; commonly translated as "dry landscape"; see Mansfield & Richie, 2009).

Chapter 1 Introduction

This work deals with human thinking in design. Specifically, we study the ways in which spatial configurations are attributed with meaning, via cognitive processes of interpretation. Figure 1-1 below shows two triangles which bear no special meaning when put side by side in (a). However, when overlayed in (b) they form the "Star of David" - an important religious symbol in the Jewish tradition[5], which also appears on the Israeli flag (c).

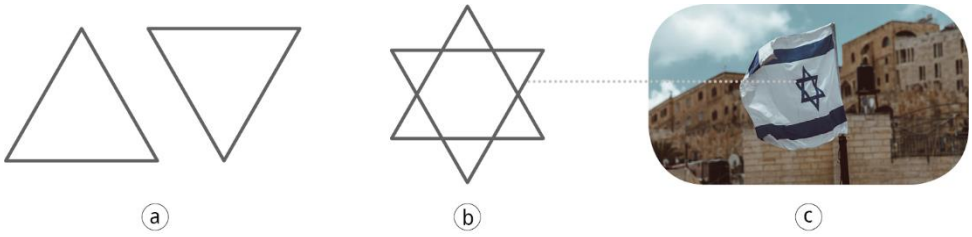

Figure 1-1 Spatial organization and interpretation; (photo by Taylor Brandon, unsplash.com).

The point here is that the same set of objects invites the attribution of different meanings under different configurations, and accordingly different worlds of content, association etc. Since designers are often required to configure forms in space, it is important to understand how they relate forms with meaning. In other words, it is important to study how they engage in interpretation.

This chapter provides a structured introduction of our inquiry into interpretation in design, in several phases: first, we present the general theme of interpretation in some detail, point out various pitfalls in its study and clarify our motivation for setting on this journey. Second, we lay out our research aims, and draw the boundaries of this dissertation. Third, we identify gaps in our current understanding of interpretation activity, which expose our window of opportunity, thus leading to the formulation of our research question. Finally, we present our hypothesis, and decompose our research question into manageable sub-questions, which are approached within the work.

1.1 Theme

> *"A man found that his axe was missing, and suspected his neighbor's son of having taken it. Observing the youth walking around, the man was convinced*

[5] And curiously, in other cultures as well; in Japanese basketry it is referred to as "かごめ" ("kagome" or "basket-eye").

> *that his was the walk of a thief. The youth looked like a thief and talked like a thief; everything he did pointed to his having stolen the axe. Then one day the man happened to find his missing axe. After that, he noticed his neighbor's son wasn't behaving like a thief anymore" (Liezi, Traditional Daoist text)*

As human beings, we can hardly avoid interpretation. The way in which we see the world is subject to our interpretation of what we see. The tale in the epigraph illustrates two important points regarding interpretation: first, its power to shape our view of the world; we see here how one event (a missing axe) leads to an interpretation of the situation (that the neighbor's son stole it), which in turn determines the way in which the world is experienced (his behavior seemed like that of a thief). Second, the fact that ambiguity naturally invites interpretation. Keeping this in mind, what is the place of interpretation in design?

As with most non-instinctive human behaviors, design activity, too, depends on the designer's interpretation of the current situation. The manner in which one conceives of the current state of affairs will strongly affect the course of his/her design process. According to, Gabriella Goldschmidt, a pioneering design theorist in this field: "interpretation emerges as the single most important force in the shaping of design solutions" (Goldschmidt, 1988, p.235). As such, inquiry into its nature seems of great value to understanding design activity as a whole.

Another important point[6] is that interpretation also facilitates action. The man in the story could have acted upon his interpretation of the situation, by (falsely) accusing the "thief" in public and tarnishing his name, by stealing some of his belongings as an act of revenge, or even by engaging in a quarrel over the missing item. Far from being a rare case, our actions are regularly facilitated by our internal construal of the external world.

In conceptual design, where ambiguity is the rule rather than the exception, interpretation plays a decisive role. Considering the well-known schematization of conceptual design activity as "seeing-moving-seeing" (Schön & Wiggins, 1992), we can easily understand Goldschmidt's claim regarding the immense importance of interpretation in structuring design processes, as it facilitates seeing, which both precedes and follows action. Therefore, and since design is a highly intelligent behavior (Kalay, 2004), the importance of studying this practice goes beyond the domain of design, and expands well into our effort to understand human intelligent behavior.

How shall we study this complex activity, which permeates cognition and directs action? From the perspective of cognition as computation (the dominant paradigm in current

[6] This point, however, is not clearly conveyed by our tale.

cognitive sciences), striving to construct a computational model for simulating interpretation in-action seems as a worthy target. Such a model would preferably be based on empirical data from design activity, to serve as its solid foundation. Existing research has either studied interpretation by observing design activity, or suggested computational models for interpretation (on theoretical grounds), but not both.

Additionally, considering the ambiguity that characterizes interpretation activity, and the power of metaphor in conceptually framing complex design situations (Casakin, 2006), a study of interpretation is expected to benefit from considering the role of metaphor in facilitating interpretation. Despite the centrality of metaphor for thinking in general (Lakoff & Johnson, 2003), and specifically for conceptual design (Hey & Agogino, 2007), current research has yet to address the use of metaphor in design in a formal manner.

Our work serves as a first integration of the all of the above, by striving for a thought-framework of interpretation that is grounded in empirical data, based on state-of-the-art theoretical models for design cognition, and considers the essential aspect of metaphoric reasoning. This framework aims to establish a strong foundation for understanding interpretation in-action, to enable the enhancement of future computational design systems and their capacity to engage in interpretation activity.

1.2 Approach

In forming our approach for inquiring into interpretation practices in design, we rely on two fundamental assumptions: (1) on an abstract level, interpretation involves (at least) two main entities - an interpreted object and an interpreting agent[7], and (2) interpretation depends on both the former and the latter (expanded upon in the next sub-section).

Situated cognition is an emerging approach in cognitive sciences which stresses the relation between the agent and its environment, as a basis for explaining complex behavior. As such, based on the above assumptions, it is suitable for approaching the study of agent-object relations during interpretation activity. Moreover, this approach has had major achievements in artificial intelligence, serving as the basis for robot control systems which can autonomously adapt to dynamic situations.[8] Recent interest in this approach, with respect to design computing, is best reflected in the formulation of the situated Function-Behavior-Structure framework (Gero & Kannengiesser, 2004), for modeling designing in a realistic manner.[9]

[7] Excluding cases where the agent is interpreting itself, as in second-order cybernetics (Scott, 2004), these are distinct.
[8] For a detailed review see (Clancey, 1997).
[9] Here, the original Function-Behavior-Structure framework (Gero, 1990) is expanded, to address the notion of situatedness.

We utilize this approach, and specifically the above framework (further discusses in 2.2.3), for studying interpretation activity in conceptual design, and constructing our thought framework. At this point, an initial research question may be stated:

> ***How can we harness situated cognition to model interpretation activity in conceptual design, as a basis for its future implementation in a computational system?***

1.3 Five Problems in Studying Interpretation[10]

Before attending to the focus of this work, it is useful to state some general problems which arise when approaching the study of interpretation activity, which render it as a highly intricate subject. We list here various problems exemplary of the major challenges that the journey towards understanding interpretation entails:

(1) **Non-exclusivity:** for a given object, interpretation is not unique. There is no singular mapping between structures and their interpretation. This fact is related with the "no-function-in-structure" principle (De Kleer & Seely Brown, 2014), which is also expressed as "the teleology of an artifact is not found in its structure, but is a contextual interpretation of its behavior" (Gero, 1996).

(2) **The role of the agent:** for any given object, interpretation depends not only on the object itself but also on the interpreter, and to some extent is a function of, as well as reflection of its internal state; this is true in the case of non-human animals as well, see (von Uexküll, 1934).

(3) **The effect of being situated:** from (1) and (2) we see that neither the object nor the agent are sufficient in determining interpretation. This is further complicated by the fact that the same person may perceive or experience the same object in different manners, in different situations, reflected in Kurt Lewin's saying that "A physically identical environment can be psychologically different even for the same man in different conditions" (Lewin, 1936, p. 24-25). The agent does not exist independently from the world, but is situated within in, and consequently is in constant transactions with it.[11]

(4) **Relation with metaphor:** interpretation is tightly linked with metaphor, which is yet to be fully understood as a linguistic phenomenon (Eco, 1986). Although we have promising accounts from a computational perspective (Searle, 1990) and more recently from a cognitive-

[10] Inspired by Searle's account of problems in the philosophy of mind (J. R. Searle, 2004).
[11] Slightly paraphrasing Heidegger - being means being in the world (Heidegger, 1962).

linguistic perspective (Lakoff & Johnson, 2003), we are far from a complete understanding and formalization of its workings.

(5) **The unconscious:** interpretation and action are both partly shaped by the manners in which the unconscious affects the conscious. However, the unconscious is not directly accessible nor easily expressible; as explained, for example, by Jung in (Jung, von Franz, Henderson, Jacobi, & Jaffe, 1964).

1.4 Swimming in the Sea of Interpretation

Considering the dimensions of the problem, it is essential to further clarify and define our target of inquiry within interpretation activity. Which part of this activity should we focus on? This question can be paraphrased as follows: what strategy or design ability do designers often utilize for interpretation in conceptual design? From the literature dealing with interpretation in design, one ability clearly stands out. This is the ability of "seeing as" (Goldschmidt, 1991; Schön & Wiggins, 1992; Stones & Cassidy, 2010). In Fig. 1-2 we see the famous "duck-rabbit" image, which exemplifies in a clear way how the same object can be seen as either a duck or a rabbit, depending on our interpretation.

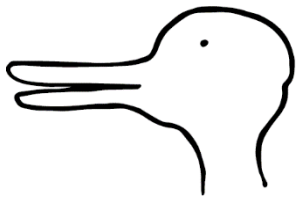

Figure 1-2 The famous "duck-rabbit" as an example of seeing as (redrawn from Wittgenstein, 1958). [12]

In the context of design activity, designers constantly rely on such "visual flexibility" to both conceive and reconceive of the design. In conceptual design, we often deal with scaled representations. Since these are abstractions of the designed artifact, they are often ambiguous, allowing different interpretations (Fig. 1-3). Conceptual design, therefore, is abound with opportunities for "seeing as", and the way we "see as" emerges as a strong candidate for our inquiry. We believe that modeling this ability can serve as an important foundation for studying interpretation in design. We now restate the general research question tentatively as follows:

[12] In fact, Wittgenstein in-turn borrowed this figure from the American-Polish psychologist Joseph Jastrow (1892).

How can we implement the ability of "seeing as" in a computational system?

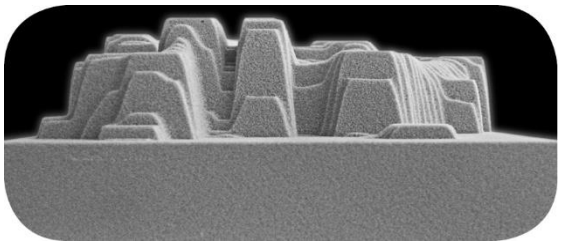

Figure 1-3 An abstract scale model used in designing a building complex; manufactured using CNC milling; work by the author, 2011.

1.5 Motivation

We have already touched upon our general motivation for dealing with the problem of interpretation, towards modeling this practice. However, it is necessary to clarify the specific motivation for studying this issue as defined in our initial problem statement. Professional designers from all fields are capable of reinterpreting design representations, which enables them to reconceive of their goals and change their view of the design problem, in a highly adaptive manner (see Rowe,1986; Boden, 2004). We hold a deep sense of admiration for this ability, that we wish to study in depth. As Richard Feynman wrote on his blackboard at his time of death: "What I cannot create, I do not understand".[13] By this philosophy, formalizing this practice and implementing it in a computational system, may help us to:

(1) deeply understand human cognition, which is of high value in itself.

(2) construct computational design systems displaying adaptive capabilities similar to those of human designers, resulting in highly robust design agents.[14]

1.6 Opportunity

This study is driven by the following views, which expose our window of opportunity:

(1) The physical symbol system hypothesis (Newell, 1980), which claims that cognitive activity[15] requires grounding in a symbolic form. With respect to artificial intelligence, it propagates the view that symbolic processing is sufficient for generating intelligent behavior.

[13] Quoted in (Hawking, 2001).
[14] Such systems can potentially support human designers effectively or work autonomously on complex design tasks.
[15] Cognitive activity which enables intelligent behavior.

Despite repeated criticism and attacks, the hypothesis still stands, to a large extent (Nilsson, 2007). We do not expect a symbolic construct to serve as the sole component of intelligent computational design systems, but rather for it to be incorporated with sub-symbolic components (such as artificial neural networks).[16]

(2) Although many successes have been achieved based on the view of situatedness as "cognition without representation", these have been mostly in tasks which may be seen as "low-level cognition" [17]. If we would like to attend to higher level cognitive tasks, some symbolic representation seems necessary. Specifically, in the case of conceptual design, it is clear that without symbolic representation, it is difficult if not impossible to make progress in a design process. In his influential work "Being There", Clark offers us a middle road which takes this approach, i.e. considers the necessity of linguistic symbolic representation for achieving higher level tasks, but without letting it "take over" the whole system or solely account for its intelligence (Clark, 1998).

Based on the above, we believe that striving towards an understanding of the practice of seeing as, with the aim of capturing key aspects of it within a symbolic form, can have significant implications to artificial intelligence.

1.7 Aim & Focus

The aim of this work is to deepen our understanding of the complex human cognitive capacity for interpretation, which enables designers to behave intelligently and adapt to dynamic situations. Such an understanding is expected to shed light on key components and processes that may serve as the foundation for computational design systems engaging in interpretation activity.

Considering the complexity of the problem[18], we focus on a single aspect which we see suitable as a stepping stone for successfully modeling this activity. This aspect is the visual interpretation of physical objects, which the designer interacts with during the design process. To explain our rationale for this decision, we briefly introduce a widely-accepted formal model for design, termed as "The Function-Behavior-Structure Ontology" (FBS), proposed by Gero (1990).

The FBS framework was originally developed in order to enable to implement design processes within computational systems. Accordingly, it separates design activity into discrete components, which may be used for knowledge representation in computational

[16] As suggested by recent research in artificial intelligence (Garcez et al., 2019, also see 2.4.3).
[17] For a detailed review, see (Clancey, 1997).
[18] Refer back to 1.3.

design. According to this model, the fundamental components required to formally describe design processes are: functions, behaviors and structures. We introduce these three components below:

(1) "Structure" refers to the physical body of the artifact (or its representation); (2) "Behavior" refers to properties or capabilities that the structure possesses; (3) "Function" corresponds with the purpose for which the structure is made (Gero, 1990; Gero & Kannengiesser, 2004).[19]

A concrete example would help in clarifying the above. Consider a standard sliding door which may be installed at your home between the living-room and balcony. The physical body of the door (including the frame, handle etc.) is the structure. In this structure, various functions can be identified. For example, one main function would be to separate the two spaces. Separation here can be further broken down into sub-functions, such as acoustic separation, visual separation and so on. Similarly, by observing the structure, i.e. the door parts, various behaviors can be identified. For instance, the whole door can move from right to left and vice versa.

Our work deals with interpretation. If we take interpretation in design to be a large task composed out of smaller parts, we can use Gero's framework to describe it as the product of three main subtasks: interpretation of functions, interpretation of behaviors and interpretation of structures. Which subtask should we focus on? Considering that both functions and behaviors are defined in relation to structures, the subtask of interpretation of structures seems as the best candidate for our initial inquiry.

Our focus on interpretation of structure is further justified by the fact that it is the most concrete out of the three main entities used to describe design activity, when considering design through the FBS framework.[20] Fig. 1-4 summarizes the above and presents the interpretation of structures as an important subtask within the more general task of interpretation in design.

[19] These are described by Gero as "what the artifact consists of", "what it does", and "what it is for", accordingly (Gero, 1990).
[20] Since "structure" refers directly to artifacts, we can easily agree that it is less abstract than both "function" and "behavior".

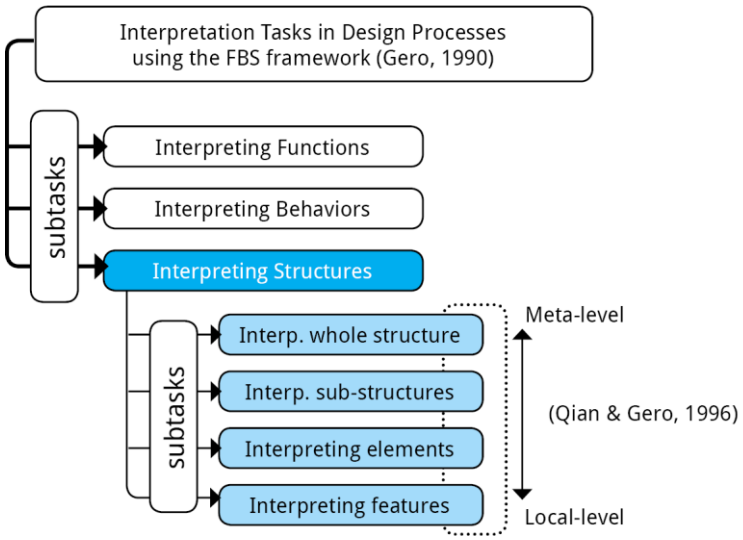

Figure 1-4 Levels of interpretation in design activity, focusing on interpretation of structure.

Figure 1-5 Physical objects as possible abstraction for other objects, facilitating RI: (a) A cardboard model for a residential unit, work by author, 2013 [21]; (b) A pile of paper which can be seen as a snowy mountain.

Additionally, while a definition for "interpretation" was previously given[22], we introduce it here as well, for clarity and readability purposes. By "interpretation" we refer to a specific interpretive act, in which a designer lets some part of the structure (i.e. the physical object and its parts) stand for something other than itself. This act is reflected in the assignment of a symbolic description to the structure or to one of its parts, denoting a set of referents that the interpreted object stands for. We refer to this act of interpretation as "representational interpretation" (RI). Above are two examples for RI which occur at different degrees of abstraction (Fig 1-5).

Depending on the ambiguity of the structure, the relationship it bears to its referent may seem strong (a) or weak (b). Both of these cases, however, share the basic fact that the viewer "looks through" the structure and "sees" its referent. This practice, which is related with the

[21] Produced under the instruction of Prof. Joseph Cory and Arch. Ruth Ron.
[22] Under "Important Terms and Definitions".

idea of "epistemic transparency", is further discussed in 2.1.3. At the moment, it is important to understand the notion of RI as letting one object stand for another, in a broad sense which includes these different cases. Under this definition, we can easily grasp the pervasiveness of RI in conceptual design, spanning from practical prototyping and up to abstract form exploration.

1.8 Problem Statement

Based on the discussion so far, we state our research problem as follows:

> ***How can we deepen our understanding of representational interpretation (RI) of structures in conceptual design, to both enhance computational design systems and extend our knowledge of human cognition?***

1.9 Boundary of Current Knowledge

We briefly state several of the main limitations of current knowledge, with respect to interpretation activity as we have construed it, directly relevant to our efforts: [23]

(1) **With respect to design theory:** currently there is no thought-framework for describing interpretation in action from a holistic perspective. Rather, there are only disparate explanations of different phenomena, which shed light on the matter from various angles, but are difficult to integrate into a cohesive image of this practice; for example, see the important work by Goldschmidt on the role of interpretation in architectural design (Goldschmidt, 1988).

The closest achievement to a unified framework is the work by Schön, who has described designing as an interaction between "rules, types and worlds" (Schön, 1988). While this work included a discussion of important elements which are central to visual interpretation activity (for example, the effect of spatial gestalts), it did not focus on interpretation practices, but rather on conceptual design in general. Consequently, it did not explain how these can they be organized to form a coherent thought-framework, which enables to systematically understand and formalize human interpretation activity.

The major limitation, however, which is applicable to all current approaches for describing interpretation activity, is that it they lack in their ability to describe the mental content which both characterizes and enables interpretation in design. In simple words,

[23] These are expanded upon the next section of "Theoretical Background".

interpretation depends on the agent's ability to have a "mental picture" of the design, which reflects his/her view of the artifact. While this mental picture is presupposed by our best models for design activity, no approach clearly discusses it in a systematic manner.

(2) **With respect to computational design:** the subjective dimension of cognition, which characterizes interpretation (as we have construed it), is only included in computational design systems to a very limited extent, and in a manner which does not enable to symbolically relate interpretations with structure in a realistic manner (i.e. as done by human designers).

1.10 Objectives & Scope

In accordance with the above, the main objective of this research is to construct a thought framework for interpretation activity in conceptual design, which has one foot in empirical data from design activity and another in theoretical models for designing. This framework is expected to describe interpretation as an activity which considers both the external state of the world and the internal state of the agent, and the relation between them. We state two main objectives:

(1) lay the theoretical foundations for systematically dealing with interpretation by identifying key entities which lie at the basis of this practice

(2) suggest how the above may be integrated into a coherent thought framework, which enables to understand interpretation in-design from a holistic perspective

In pursuing these objectives, we set the boundaries for our inquiry as follows. First, while visual interpretation may occur in various phases of the design process, this work focuses on the conceptual phase of design activity. This is due to the fact that it abounds with ambiguity, which necessitates continuous interpretation by the designer.

Second, in dealing with RI, and for the purpose of simplification, we have found it useful to focus our inquiry on the visual expression of spatial relations between design elements. This approach has guided us throughout the work: in selecting our design domain to serve as a case study, in designing our task for collection of empirical data, in the analysis of this data and in the extraction of important findings. Accordingly, the effect of other visual factors on interpretation, such as color and texture of the design elements (intentionally minimized in our design task, see 3), were not attended to. These aspects add a layer of complexity to visual interpretation activity, which cannot be disregarded. However, considering that this work serves as a first step for developing a systematic understanding of this practice, a gradual integration of additional visual factors into the work will be required in the future.

Third, this work does not include an account of the following:

- how personal traits or characteristics of the interpreting agent shape the activity (for example, personal preferences etc.)
- in accordance with the previous item, the effects of personal background and domain-specific knowledge on interpretation (for example, education in a certain discipline etc.)
- similarly, the aesthetic dimension of the design (for example, stylistic considerations used in the creation of the artifact)
- how the current cognitive state of agents is affected by their bodily state (for example, by hunger/thirst)

We see all of the above as higher-level factors, which substantially increase the complexity of the analysis, and can effectively be inquired into after a basic model for the activity is established. Such a model may be complemented by multiple layers for filtering potential interpretations, based on the above. Of course, once the different layers are constructed, they will preferably be integrated, so that various considerations may interact, as occurs in real design processes.

1.11 Significance

As previously established, interpretation is central to design activity, and as such, a worthy topic for research. [24] Accordingly, this research contributes to our understanding of interpretation processes in design. By providing a framework for understanding this ability, our work bears a double contribution: first, to design science and second, to artificial intelligence in design.

From the perspective of design science, this work furthers our ability to model interpretation activity, and therefore contributes to:

- facilitating systematic inquiries into interpretation in conceptual design, in order to formalize interpretive practices for their implementation in computational design systems
- putting the current dominant theoretical frameworks for situated design[25] to the test, by applying them for modeling interpretation activity. This includes both a

[24] Refer back to 1.1.
[25] Most notably, the Situated Function-Behavior-Structure (Gero & Kannengiesser, 2004).

demonstration of their applicability to real-world design activity and the suggestion of potential ways for extension, based on our findings

From the perspective of artificial intelligence in design, this work takes a step towards capturing metaphoric interpretations within formal descriptions. This enables us to propose concrete ways for extending the knowledge representation capabilities of digital design systems, contributing to:

- the enhancement of CAD support systems for conceptual design, by informing them of high-level features of the artifact, which are of a subjective nature; thus reducing human-machine gaps in understanding digital design representations
- such features can serve as the basis for high-level automated reasoning, by integrating CAD environments with logical-inference engines. Accordingly, they can be used to extend the ability of CAD systems to interpret structures, which can enhance both co-creative systems (supporting the user via suggestions) and autonomous agents (which are implemented to perform a task involving interpretation)
- storing subjective features within formal descriptions opens the door for sharing collections of interpretations among designers, thus potentially deepening the collaborative dimension of CAD-based design processes

1.12 Hypothesis & Problem Decomposition

Assignment of RIs is often seen as a serendipitous or improvisatory act. Despite this, we hypothesize that it utilizes certain cognitive abilities which can be modeled. Specifically, we claim that while interpretations may be assigned on a potentially random or nontraceable basis, changes in interpretation occasionally involve acts of reasoning, which can be traced and modeled.

To examine this hypothesis, our research question[26] is further broken down to the following four questions, each explored in this work in a separate chapter, to facilitate a rich understanding of this practice:

(1) How can we approach the modeling of RI activity?

(2) How can we formally represent RIs in conceptual design?

[26] Refer back to 1.8.

(3) How can we model the assignment of RIs in-action, in conceptual design?

(4) How can we model the designer's perspective during the assignment of RIs?

1.13 Overview of the Work

This sub-section outlines the structure of the work, to enable readers to navigate through the dissertation, and follow our thought and research process. The reader can refer to Figure 1-6 below, which complements the following explanation.

The work generally consists of four parts: (1) introducing the topic, theoretical background, etc., (2) developing the methodology, (3) executing projects targeted at examining our research questions, and (4) reflecting upon our findings from a holistic perspective.

The progression of the research may be summarized as follows: in part 1, we have raised our general research question, presented in the previous section. This question has led to the development of an initial CAD-based method (M1), which was executed in two projects (P1, P2), each yielding a contribution to our knowledge of modeling RI (C2, C3 accordingly), and deepening our research questions (Q2, Q3 accordingly). This resulted in the sophistication of our methodological approach, via the development of a complementary method of design observation (M2), which was applied in the following projects (P3, P4). Note that, as evident from Fig. 1-6, the work was not conducted in a pure linear manner, but as a process involving continuous reconsideration of our perspective, in accordance with our findings.

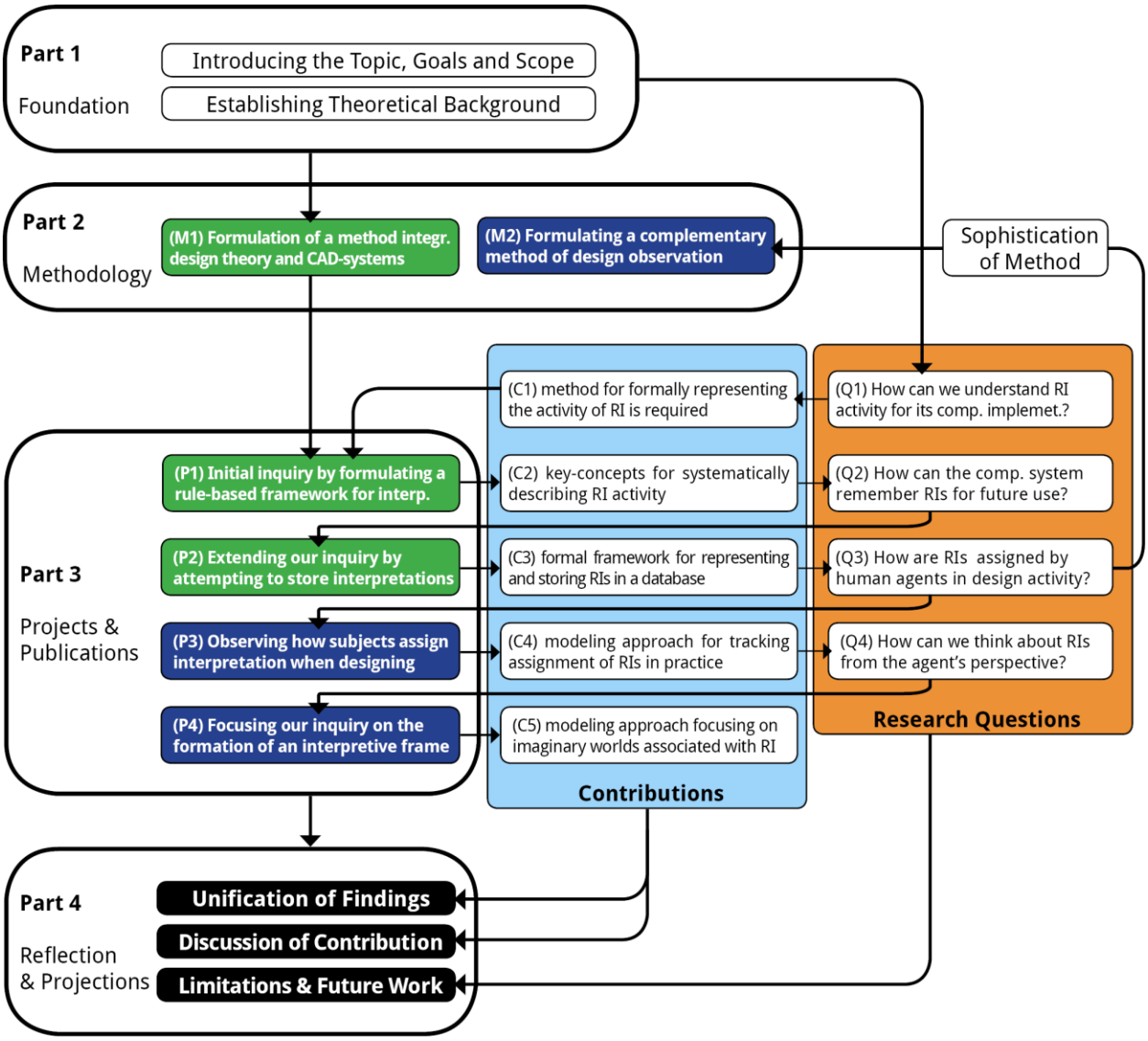

Figure 1-6 The structure of this work

Additionally, we provide a summary of the rest of this work, by concisely presenting the contents of each chapter, as follows:

- **Chapter 2**: covers the theoretical background for this work, by reviewing relevant literature from multiple angles and fields, including: interpretation in design, situated cognition and design, knowledge representation and reasoning, computational design systems, metaphors & world-making and JRGD.

- **Chapter 3**: presents the general methodology for this study, which has guided the design and execution, as well as integration of all sub-projects in this work.
- **Chapter 4:** develops an initial thought framework and a set of concepts for systematically approaching RI, by studying the interpretive practices of JRGD. this consist of the proposal, implementation and testing of a computational framework for translating RIs into structures in design.
- **Chapter 5:** demonstrates the possibility of symbolic representation of RIs within a computational system. This is done by proposing, implementing and testing a knowledge representation framework, in the context of JRGD.
- **Chapter 6:** explores the assignment of RIs in-action via observing and analyzing design activity, in the context of JRGD. In this, we propose a way to model RI assignment, based on existing frameworks for situated design.
- **Chapter 7:** further studies the aspect of subjective understanding of interpretation activity by the designing agent, using our design task. Here, we demonstrate how the designer's perspective during RI activity can be modeled, visualized and understood, via utilizing frameworks for situated design, as well as theories from discourse analysis and the philosophy of mind.
- **Chapter 8:** considers our various findings from a holistic perspective, discusses our achievement, its implications and the main limitations of the work.
- **Chapter 9:** discusses potential future directions, and concludes this dissertation.

Chapter 2 Theoretical Background

2.1 Visual Interpretation in Conceptual Design

To date, research on interpretation in-action has been conducted mostly in the context of architectural design, by analyzing the manner in which designers engage in it during conceptual design activity. Important studies in this field have dealt with: (1) the manner in which the design task itself is interpreted (Goldschmidt, 1988); (2) the role of seeing in design (Schön & Wiggins, 1992; Suwa, 2003; Suwa & Tversky, 1997); (3) the role of interpretation in conceptual design (Gürer, Özkar, & Çağdaş, 2014); relating interpretations with expectations (Kelly, 2011) and more. This section reviews such central works for elaborating our view of interpretation in conceptual design. In this we identify important concepts to serve as a basis of our thought framework.

2.1.1 The Pervasiveness of Interpretation

> *"As soon as you see something, you already start to intellectualize it. As soon as you intellectualize something, it is no longer what you saw"; (Shunryu Suzuki in Chadwick, 1999)*

Our lives are permeated with interpretation. We do not only take information from the environment as passive input. High level cognitive activity, whether conscious, sub-conscious or unconscious, is always at play. Immanuel Kant has long expressed this in the 18th century by stating that "perception without conception is blind." (Kant, 1998) After more than two centuries, this statement remains relevant for the discussion of seeing and interpreting. This insight is well-weaved into recent work in the philosophy of mind, as exemplified by Searle, who has proposed the interesting idea of "aspectual shape". This notion refers to the fact that any object is always seen under some framework of thought, which serves as a hidden foundation for perception (Searle, 2004). These frameworks (often referred to as aspects) shape our, perception, experience and interpretation of what we see.

Consider the simple example of a book lying on your desk. When you want to read it, you may see it under the aspect of "source of information". However, if your window is open and strong wind starts to blow, you might pick it up and place it on top of your documents as an ad-hoc paperweight, to keep them from flying in the air. In this case, the aspect is quite different, and might be called a "heavy object". We interpret the book differently, according to our changing circumstances. Of course, interpretation goes far beyond such situations, and extends into almost every aspect of everyday life. We interpret the weather outside by looking

at the sky from the window, we interpret our friends' feelings when we see them smile or cry. We also interpret the letters on this page as English.

It is important to notice that interpretation gains much power from ambiguity. Once we are unsure about what is in front of us, we are naturally driven to find an interpretation. Our interpretations usually correspond, in this way or the other, with our current cognitions. Some objects are highly ambiguous and afford many interpretations for the viewer, further intensifying the role of interpretation. Contrast, for example, the duck-rabbit (previously show in Fig. 1-2) with more multifaceted example like the famous Rorschach ink blot test, used to evaluate how individuals project interpretations onto highly ambiguous forms.

If we cannot escape interpretation in everyday life, the same applies for design activity. In visual design disciplines, interpretation comes into the picture as an integral part of seeing, and has decisive impacts for action. We do not look at objects in design in an objective, disinterred or neutral way. Rather, we see them from our own subjective viewpoint, and based on our own momentary interpretation, which is in turn affected by the current situation. When we engage in conceptual design, we almost never deal directly with the real artifact. Instead, we work with models[27], as design representations. Due to this, and considering that representations always omit certain details from the original[28], it is no wonder that working with them encourages interpretation, which then leads to discoveries and to restructuring the design process.

At the root of interpretation activity in conceptual design lies a phenomenon referred to as "seeing as"[29]. The next sub-section discusses this important notion, which is at the heart of our inquiry into the human capacity for interpretation.

2.1.2 Interpretation and Seeing: Seeing As

The notion of "seeing as" was first suggested by Wittgenstein, to refer to our ability to "see" one thing as another. The image presented in the introduction (Fig. 1-2), which served as our first example for this phenomenon, was borrowed from his famous book "Philosophical Investigations" (Wittgenstein, 1958), and demonstrated the manner in which we may look at a figure, which is constituted of marks on paper or on our screen, and see it in different ways. In this act of seeing, we are interpreting the image.

As an example in the context of conceptual design in architecture, examine the figure below, which is taken from a design task demanding the positioning of entrances to a library building. The same architectural plan was seen by the subject in two different manners, at

27 Whether physical or virtual.
28 Refer to the famous tale "On exactitude in Science" by (Borges, 1975).
29 Briefly mentioned in the Chapter 1.

different times. The plan to the left, i.e. (a), is interpreted once as "central space and three pods" in (b), and later as "Two L's Back to Back" in (c) (Goldschmidt, 1991) . The manner in which the designer saw the building's footprint in terms of smaller units has determined his/her approach to positioning the entrances, and thus had significant consequences for the design process.

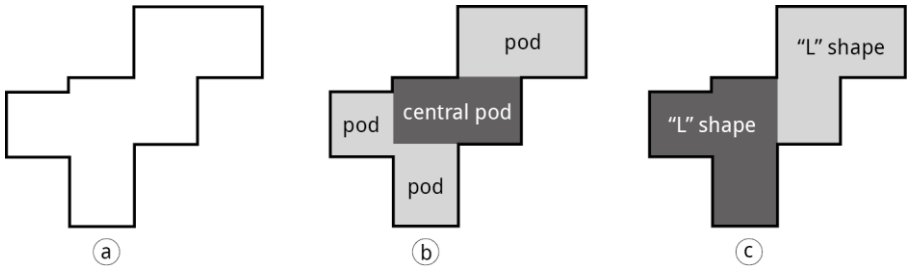

Figure 2-1 Two different visual readings of one architectural plan for a library by a subject. (a) original plan as given in the design task, (b) seeing it as "a central space and three pods", or (c) as "two L's back to back"; redrawn from (Goldschmidt, 1991) and colored for emphasis by author.

With respect to the specific practice which we are interested in, i.e. that of letting one object stand for another, examine the World Trade Center Memorial project by Peter Walker and Michael Arad, called "Reflecting Absence" (Fig 2-2). Here, the footprints of the twin towers were replaced with a large hole, emphasizing their absence. The hole metaphorically stands for the buildings, which no longer exist. With this knowledge, we do not simply see it as a hole, but rather interpret it as a remnant of the past buildings.

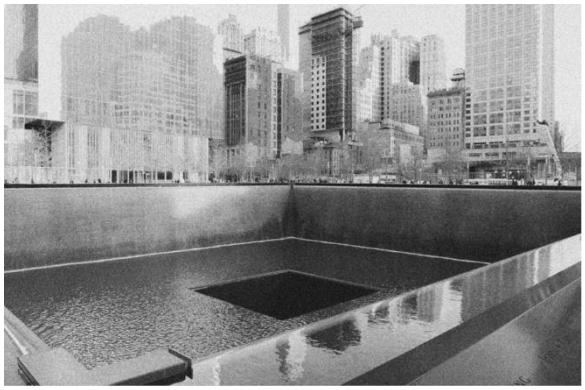

Figure 2-2 The American national September 11 memorial site. A hole as a sophisticated form of inducing "seeing as", implying on the absence of the Twin Towers (Source: Foundry Co from Pixabay).

2.1.3 Epistemic Transparency as the Basis for Interpretation

In conceptual design, designers work with design elements as models for full-sized artifacts, each postulating different transformation between the model and the design to be executed. However, in all cases, of course, the designers are aware that they are dealing with a model. As such, to use Liddament's term, the materials in front of them are taken as "epistemically transparent" (Liddament, 2000). Viewing the model as a "picture" of the future artifact, we can further quote:

> *"For us to be able to see what is in the picture, it must become 'transparent' to us in a sense which transcends the transparency of the primary conceptual field. To do this one must grasp the use of the picture as a representational device." (Liddament, 2000, p.601)*

In the same manner, conceptual design tasks demand designers to look at the materials as 'transparent' and attempt to see the real objects which they stand for, which will comprise the artifact to be actualized in the future. When designers invoke the power of metaphor to assign interpretation to object, they can detach from the representational object itself towards its interpretation. In this sense, metaphor works in the service of epistemic transparency, enabling us to engage in interpretation activity its full sense (more in 2.5).

2.1.4 Relevant Work

We review current research which deals with interpretation and is relevant to our work. The major part of such research was conducted in the context of architectural design activity. Different researches have studied how designers see and interpret designs by documenting and analyzing conceptual design tasks.

First, as a pioneering researcher in this field, Goldschmidt has studied the role of interpretation in architectural design, by examining the manner in which a design task is interpreted, i.e. how designers construe a task which is loosely defined (Goldschmidt, 1988). In this experiment, architecture students were requested to design a dwelling unit. All students started with the same cubic volume, which could be manipulated by adding or removing parts, and were requested to produce a design for a private house that will adhere to the idea of a "cube". When the task was completed, the student ended with very different results. Goldschmidt has shown that different designers construe the same task differently, and therefore that interpretation has a major role in shaping design solutions. The final result depended on the initial interpretation of what a "cube house" meant for each student. In Goldschmidt's later work titled "The Dialectics of Sketching", she proposed the distinction between "seeing as" and "seeing that", which can serve as a basis for understanding the different functions of seeing in design (Goldschmidt, 1991).

Other researches have extended this inquiry into the roles of seeing in design: Schön and Wiggins have discussed different kinds of seeing in design, further distinguishing between "seeing that", "seeing as" and "seeing in". They stress that seeing is not a passive activity, but rather an active one of engaging with the design and interpreting it: "the designer not only visually registers information but also constructs its meaning". Accordingly, they propose to see design as a "conversation with the materials", a perspective which stresses the interactive nature of designing, consistent with the views of design as a situated activity (discussed later). By analyzing data from architectural design tasks, they draw a picture of design activity as "seeing-moving-seeing". The designer "sees" the design, acts based on what he/she sees, and acts again (Schön & Wiggins, 1992).

Suwa and Tversky have examined the manner in which architects interact with visual representations, focusing on what they "see" in their own sketches, i.e. what information they extract from them, and how it is utilized. They concluded that focus-shifting [30] and subsequent exploration of successive thought are both essential drivers in the design process (Suwa & Tversky, 1997). Integrating the above schematization of Schön & Wiggins and the results by Suwa & Tversky, we could describe design as seeing-reflecting-moving-seeing.

In a later work, Suwa further found that the ability to recognize multiple interpretations in ambiguous forms depends on skill, which he refers to as "constructive perception" (Suwa, 2003). This skill is described as a form of self-awareness to the manner in which perception facilitates one's current interpretation of a visual figure. This means that our ability for interpretation can and needs to be trained, in order for us to make use of our full potential of interpretation in the design process, as designers of any visual discipline. It also means that we can speak of degrees of skill in terms of our capacity for interpretation, and that interpretation itself is subject to higher level cognitive processes, which enable its regulation and control.

From a more general perspective, Gürer et. al have discussed the role of interpretation in conceptual design, and its relation with action. By letting designers reflect on their designs in writing, they provided them with an opportunity for distancing themselves from the artifact, and reassessing it. Such distancing enabled changing their thinking mode from designers to interpreters of their own designs, thereby enriching their interpretive output. According to Gürer et al. "design is assumed to begin where prejudices (such as initial perspectives, design languages and more) meet an explicit situation" (Gürer et al., 2014, p.170). This stresses the two-sided nature of designing as an encounter between the agent and the materials, which largely coincides with views of situated designing. [31] The link

[30] For example, between different gestalts.
[31] See next section.

between the two is, of course, formed by the interpretation of the materials based on the agent's current "prejudices". They concluded that design can be driven by a "dialog" of making and writing, reminiscent of Schön and Wiggin's metaphor of "design as conversation" mentioned above (Gürer et al., 2014).

Several conclusions can be drawn from the existing work, and the manners in which interpretation has been previously studied: (1) most existing work is based on architectural design practices; (2) nearly all works utilize design protocols as a major part of their study; (3) key insights from the works in this field are presented as general guidelines and identification of important cognitive phenomena, but commonly do not include specific models which account for their structure, internal dynamics etc.; (4) key works in the field do not rely on formal models for design activity[32]; (5) in accordance with (3) and (4), few works provide us with formalizations of interpretation practices, which can be implemented in computational systems.

An exception to the above is the research done by Kelly, which proposed a formalization for an aspect of interpretation activity in design, namely the relation between expectations and construction of interpretations (Kelly, 2011). This research included the development of a formal model, as well as a computational implementation, which demonstrated how visual interpretations may be constructed, based on an agent's expectations. The proposed model makes a distinction between "push-only", "pull-only", and "push-pull" interpretation, with respect to how the interpretation emerges in relation to the agent's memory and expectations. Kelly has utilized the formal model of situated FBS for his research, as a basis for distinguishing between the objective state of affairs in the external world, and its subjective reflection in the interpreted world (Gero & Kannengiesser, 2004).

We take a similar approach, and utilize the same formal model as a basis for our work. However, in contrast, instead of developing a method by which future interpretation may be computationally accounted for, based on the current state of the agent, we are more interested in understanding the relations between the interpretation and the structure. This is necessary for symbolically describing RIs, in order to facilitate high-level reasoning in a computational system.[33]

[32] Such as the situated FBS framework; (Gero & Kannengiesser, 2004).
[33] See further in 2.3.

2.2 Situatedness in Design

2.2.1 The Situated Approach to Cognition

Situated Cognition is an umbrella-term for a collection of approaches in cognitive science which share a basic philosophical stance in the study of cognition, as well as several key guiding principles. The main philosophical foundation can be generally traced back to ideas found in Dewey, Heidegger, Merleau-Ponty, among others (Gallagher, 2001). Its core stance can be grasped in the following quote by Dewey: "The idea of environment is a necessity to the idea of organism, and with the conception of environment comes the impossibility of considering psychical life as an individual, isolated thing developing in a vacuum." (Dewey, 1884). This aligns well with Heidegger's notion of "being in the world" (Heidegger, 1962). The key point is this: people do not exist in an empty or neutral space. We perceive, reason, and function in specific physical environments, which we cannot detach ourselves from. Cognitive activity essentially takes place within concrete situations and using physical materials which play an important role in its facilitation. This results in an emphasis on agent-environment relations, as a basis for studying and understanding cognitive activity.

This basic stance is further elaborated by the various approaches which fall under the term. Several of the main approaches propagating situatedness are:

- the embodied approach, emphasizing the role of the body in facilitating cognition; see (Johnson, 1990; Shapiro, 2011; Varela, Thompson, & Rosch, 1993),
- the extended approach, stressing the extension of cognitive activity beyond the body and into the environment; for example (Wilson, 2004),
- the enactive approach, emphasizing the dependency on the activity of the agent, for example (Hurley 1998).

For a brief review of the main approaches associated with situated cognition see (Wilson, 2002). For an overview of the field, see Andy Clark's seminal work (Clark, 1998). Finally, Cheng has recently provided us with a review of different types of situatedness in animals (Cheng, 2018).

It is important to mention that, beyond their theoretical appeal, these approaches have had major success in facilitating the construction of intelligent control systems, enabling highly adaptive behavior in robotic systems, via a close coupling with the environment. Since interpretation, as we have construed it, is necessarily an interaction between an agent and an interpreted object in the environment, such success points to the strong potential of situatedness for contributing to the development of artificial intelligence systems for interpretation in design. Accordingly, we present several products of this approach in the

following sub-section, as examples for its contribution to engineering and design of intelligent systems capable of real-time action.

2.2.2 Successes of Situated Cognition

Rodney Brook's subsumption architecture, elaborated in his famous work "A Robust Layered Control Architecture for a Mobile Robot" (Brooks, 1986), proposed a control architecture which enables moving robots to perform well in navigation and interaction with the environment, by forming a reactive hierarchy of behaviors, which does not depend on pre-planning for action. The system senses and responds in real time, adapting its behavior to the dynamic conditions of the task, caused by changes to the environment as well as the position of the robot within it. The success of this architecture is evident in the later establishment of "iRobot", the world-famous manufacturer of autonomous robots for floor cleaning and maintenance.

In another case, Fukuda and Saito have managed to replicate the brachiation movement of apes (swinging from one branch to another), based on a situated approach. In this case, success was achieved using a neural-network for learning the different values of actions at different times, with respect to the state of the robotic arm in relation to the "branch" in the environment (Fukuda & Saito, 1996).

For a detailed review of artificial intelligence systems such as the above which, to some extent, find their basis in the situated cognition approach, see (Clark, 1998), as well as (Clancey, 1997). More recently, and in the context of computational design systems which is closer to our area of interest, Kelly has demonstrated how visual interpretations may be constructed, based on the expectations of the interpreting agent (Kelly, 2011). In this work, a framework for modeling interpretation was proposed based on current situated design models, and implemented using self-organizing maps.[34] This suggests the direct relevance of situated cognition for the development of computational design systems, and specifically for interpretation.

2.2.3 A Framework for Modelling Situated Design

Many efforts have been made to construct formal models for design, as a basis for computational design systems. Most notably, Gero's Function-Behavior-Structure (FBS) ontology has established a general foundation for systematic representation of design processes, enabling their implementation in computational systems (Gero, 1990). While significantly contributing to our understanding of design[35], this model did not address certain important aspects of the design process.[36] For example, the differences between the external

[34] Commonly referred to as SOM; also called Kohonen Maps.
[35] And its formalization towards the development of artificial intelligence in design.
[36] As noted by its creator.

objective world and the internal subjective world of the designer. In order to bridge such gaps between our knowledge of designing and existing design models, the original FBS framework was extended, based on the notion of situated cognition, resulting in the situated Function-Behavior-Structure (situated FBS) framework (Gero & Kannengiesser, 2004). We briefly introduce this later framework, which serves as our basis for modeling interpretation activity in this work.

The situated FBS framework distinguishes between three worlds in which design activity takes place: an external world, an interpreted world and an expected world (Fig. 2-3). The external world deals with the representation of structures existing outside of the agent. The interpreted world, in turn, deals with the manners in which the agent subjectively conceives of the external world. Finally, the expected world deals with future states that the agent intends to bring about via design activity, and based on the contents of the other two worlds, which frame his current view of the design. The model further specifies different transformations which occur between its fundamental design entities (function, behavior, and structure) across these worlds, enabling its application for analyzing and formalizing design activity.

Figure 2-3 Design worlds of the situated FBS; adapted from (Gero & Kannengiesser, 2004).

It is important to further clarify the nature of the relation between design and situated cognition. As in the case of most human activities, the concrete circumstances in which designers are found, when designing, affect and shape their design process. On this basis, design is seen as a situated activity. According to Gero and Fujii, actions in design are situated in the sense that they result from the designer's interaction with the changing environment, as the design process progresses (Gero & Fujii, 2000). Furthermore, with respect to the role of situatedness in design, Gero suggest the following: "Situatedness can be seen as a means by which the designer changes the trajectory of the developing design. Different situations provide different opportunities to move in different directions" (Gero, 1998b).

Both of the above relations between situatedness and design are tied with the important notion of "reflection-in-action", propagated by Schön, which is an essential component of our understanding regarding how professionals perform in their area of expertise, in real-time (for a general discussion on the subject with respect to professionals of different fields, see Schön, 1984; in the context of visual design see Schön, 1992). Therefore, situated cognition has the potential of enlightening us regarding real-time cognition and action of designers in their general practices, and specifically in the manners in which they engage in

interpretation. Accordingly, we utilize Gero and Kannengiesser's framework as our foundation for approaching the modeling of interpretation in-action. In the following sub-section, we further clarify its stance towards interpretation.

2.2.4 Situatedness and Interpretation

As seen in the previous sub-section, the current situated model for design approaches design activity by discerning the external world from the internal world of the designer. Design activity is further seen as a set of transformations across these worlds. In the context of this work, since interpretations assigned by designers are grounded both in the external object which is interpreted, and in the designer's internal state (see 1.2), such models have a strong potential to shed light on how interpretations emerge from the interaction between designers and their environment. Among the three worlds mentioned[37], we find it important at this point to expand on the nature of the interpreted world.

The interpreted world is best seen as a kind of mediating mental environment between two fundamental aspects of the design: the current state of the design (external world) and the plans for action which one intends to take in the future, towards its modification (expected world). Thus, its importance in shaping the design process is rather clear. When designers engage in acts of seeing as, they assign an object in the external world with a symbolic description in the interpreted world. While the ink markings of the duck-rabbit drawing from Figure 1-2 exists in the external world on paper (or on our screen), its interpretation as either a duck or a rabbit exists in our private interpreted world. Of course, modifying the drawing in the external world can affect its interpretation in the interpreted world. In other words, there is a tight relation between what is there, and how we perceive and conceive of it.

In this work, we approach interpretation mainly as an activity of reasoning[38], in which entities in the interpreted and external worlds, which are symbolically represented by the agent, interrelate and interact.

2.3 Knowledge Representation and Reasoning

This section introduces the notions of knowledge representation and reasoning, as a preparation for their discussion in the context of computational design systems.

2.3.1 Knowledge Representation

To approach the matter of knowledge representation, it is important to at least briefly introduce the notion of knowledge itself. Both knowledge and the notion of knowing are

[37] The external, interpreted and expected worlds.
[38] See next section.

extremely deep and complex matters. Nevertheless, a useful foundational approach is suggested by Brachman and Levesque, who mention the following as its basic aspects:

- knowledge can be seen as a relation between an agent (knower) and a proposition
- such propositions constituting the knowledge of the agent can be right or wrong, to a certain degree

On the basis of these, they further define knowledge representation as follows: "…the field of study concerned with using formal symbols to represent a collection of propositions believed by some putative agent" (Brachman & Levesque, 2004, p.4). In our case, the agent can be either the human designer who we are studying (by experimentation) or catering to (when developing the computational system), or the computational system itself.

2.3.2 Reasoning

The literature abounds with various views of design activity, for example: design as a dialogue between the designer and the materials (Schön & Wiggins, 1992), design as invention (Zumthor, 2006), or deign as play (Goldschmidt, 1988). A highly influential view is that of design as a problem-solving activity (Simon, 1996). In this view, the agent (designer) attempts to change the current state of the world, which is unsatisfactory in some sense (and therefore poses a problem to be solved), into a preferrable state (Fujii, Nakashima, & Suwa, 2013). Note that this view is strongly associated with representation of knowledge in a symbolic form (Newell & Simon, 1972) (which corresponds with 2.3.1 above).

To successfully engage in such problem solving, we need to be able to represent the initial state and the desired state, as well as make the transition between the two, via reasoning. In line with 2.3.1, and with the work by Newell & Simon mentioned above, we take the general view of reasoning as a process of formally manipulating symbols, which stand for the agent's knowledge (Brachman & Levesque, 2004). To further specify the notion of reasoning employed in this research, which we view as important for modeling interpretation activity, we turn to artificial intelligence.

In classic artificial intelligence, an important type of reasoning is that of deductive inference (Barr & Feigenbaum, 1981). Deductive inference can be seen as a mechanism of utilizing existing knowledge and rules for deriving new knowledge, on the basis of deductive logic. The existing knowledge held by the agent (represented symbolically via propositions) is usually referred to as "facts", and the rules as "inference rules".[39] As a simple example, consider the

[39] See Barr & Feigenbaum above.

proposition "John is a man" and the rule "if X is a man, then X has a mother", which enable us to logically deduce that John has a mother.

Conducting such inference, whether by human or computational agents, thus requires: (1) the ability to represent the facts and rules in some manner, and (2) the ability to apply the rules on the facts, in order to derive new facts. According to current theories in cognitive science, which take the computational view of mind, modeling human cognition requires us to account for knowledge representation, and processes which operate on this knowledge. Notice that these correspond with (1) and (2) above (Friedenberg & Silverman, 2006; Thagard, 2005). Therefore, in the context of this work, if we wish to model interpretation processes in design, we need to account for: (1) the knowledge held by the agent, and (2) the processes of reasoning applied to this knowledge, in order to make progress towards solving the design problem.

2.3.3 Knowledge and Reasoning in Computational Design Systems

Based on the above, and considering our focus on computational design systems, we rely on the model by Coyne et al., which further defines the basic units of knowledge as objects and relations. Objects and relations constitute facts, which in turn enable to derive new facts, on the basis of existing ones. According to Coyne et al.: "knowledge can be characterized as statements about mappings between facts" (Coyne, Rosenman, Radford, Balachandran, & Gero, 1990, p.48).

In our case, such knowledge is useful both for describing structures and for reasoning about them; a simple example is provided below in (Fig. 2-4). With this in mind, and as explained above, our work regards knowledge as sets of propositions, which are formally expressed in a symbolic form, and are believed by the designing agent (whether human or artificial).

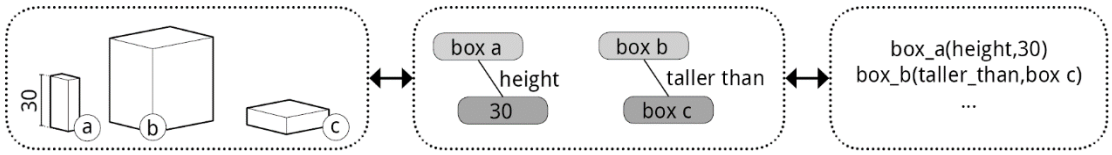

Figure 2-4 Knowledge representation using simple objects and relations; see (Coyne et al., 1990).

Such propositions can serve as the basis for problem-solving via reasoning, on the basis of inference rules, within a computational design system. For example, we could formulate a rule stating that a box is too expensive for manufacturing if its height is more than 10 units. In this case, box (a) in Figure 2-4 may be automatically evaluated (deductively) as "too expensive" via inference. This deduction can result in the addition of new fact to the agent's database, such as "box_a(cost, too_exepensive)", thus enriching its ability to both describe the current situation, and further reason about it.

2.4 Computational Design Systems

This section reviews key computational approaches in artificial intelligence, which have proved fruitful for constructing computational design systems, and are relevant for interpretation in conceptual design. We begin by presenting the two dominant camps of "knowledge-based" and "connectionist" systems, and continue with the integrative approach of "hybrid systems". Finally, we identify the contribution of each for our ability to construct computational systems for interpretation of structure, as well as the boundaries of current knowledge which are expanded by our work.

2.4.1 Knowledge-Based Design Systems

We open this sub-section by introducing the notion of knowledge-based systems (sometimes called "production systems" or "expert systems"). This will serve as our basis for discussing the use of knowledge-based design systems, which can be seen as an early form of applying knowledge for computational design.

Knowledge-based systems are artificial intelligence systems which rely on symbolic descriptions for conducting automated reasoning. The main idea behind these systems may be stated as follows: if we can capture key facts and rules about some discipline within formal descriptions and store them in a knowledge base, then we may use computation to easily draw further inferences (using what we call an "inference engine"). As mentioned by Miles and Moore (1994), these systems date as far as the 1970's. Notable examples from that period are the DENDRAL system by Feigenbaum et al., which has dealt with auto-identification of organic molecules (Feigenbaum, Buchanan, & Lederberg, 1970), and the one by Shortliffe (1976) called MYCIN, which has dealt with automated reasoning for medical diagnosis purposes.

As any form of AI, expert systems have both advantages and disadvantages. Key weaknesses are discussed in the following sub-section. Their main strengths are summarized here:

- constructing such systems makes the domain knowledge explicit, by specifying it within symbolic descriptions, which serve as the content for the knowledge base
- once the knowledge base is established, it can be used to automatically reason with respect to extremely complex structures of facts and rules
- the behavior of such systems is relatively easy to trace and therefore to debug

Knowledge-based design systems can be seen as a sub-type of knowledge-based systems, since they too rely on the existence of knowledge bases as well as inference engines, for

computationally reasoning in design. Coyne et al. Provide us with an overview of this field, as well as concrete examples for successfully implemented systems (Coyne et al., 1990). Some prominent early examples for such systems from architectural design are SightPlan, which has dealt with planning of construction site layouts (Tommelein, Levitt, & Hayes-Roth, 1989), and the EAVE system for designing roof details, as to accord with specific regional regulations (Mitchell & Radford, 1987).

In accordance with our research problem, we are especially interested in computational design systems that target the conceptual design phase. We thus chronologically review various examples, to outline the variety of applications of knowledge-based design systems, which have emerged since their inception.

A fundamental motivation for developing knowledge-based design system is the desire to reuse existing knowledge in future designs. The Argo system, developed by Huhns and Acosta, which focused on the aspect of general problem solving, utilized analogical reasoning for the transference of complete design plans between analogous design problems. Their system enabled learning from previous experience in knowledge-based design systems, by reusing previous knowledge and applying it to new problems which are analogous to ones solved in the past (Huhns & Acosta, 1992).

Generation of design solutions may also be facilitated via knowledge-based systems. In the domain of engineering, Chin and Wong (1996) reported on a system which supports material selection by utilizing a knowledge base, and further aids in determining certain features of the initial design of plastic molds. In a related research, Moulianitis et al. have demonstrated how we can generate design solutions at the conceptual design stage, using a heuristic search method, in the context of mechanical parts production for robot grippers (Moulianitis, Dentsoras, & Aspragathos, 1999). Additionally, in the context of manufacturing and assembly for physical parts, Zhang et al. have developed a system for synthesizing initial functions into physical properties at the first stages of the design process. Their system also demonstrated abilities of function-decomposition, enabling to convert complex functional requirements into sets of simpler sub-functions, to facilitate the translation of high-level functions into concrete properties of the design (W. Y. Zhang, Tor, & Britton, 2001).

By utilizing the capabilities of knowledge-based systems for automatically reasoning regarding relations between multiple elements, researchers have also developed systems which aid designers to maintain control over the initial design, in real time. Tong and Gomory have proposed a system for supporting the initial phase of product design, by making sure that essential spatial relations are maintained during the conceptual design process, thus reducing the cognitive load on the designer. Their system can also simulate local part interaction and report useful information regarding it, which may be then examined by the

user. If users become aware of problems in this manner, they can modify the design accordingly (Tong & Gomory, 1993).

Last but not least, knowledge based-design systems have also been used for shortening the initial design cycle. In the context of aircraft design, two knowledge-based system were integrated by forming a shared knowledge base, to which both systems can access. The result is a cross-platform integration between 3D modeling capabilities of the first system (RAPID) and a geometric analysis ability of the second (TANGO), to facilitate faster evaluation of design solutions at the initial design phase (Munjulury, Staack, Berry, & Krus, 2016).

2.4.2 Beyond Descriptions: Neural Networks in Service of Computational Design

The previous sub-section has discussed knowledge-based design systems and their applications, mainly in conceptual design. While these systems bear different advantages, they have failed to provide complete solutions for conceptual design processes, for multiple reasons. Among these are:

- constructing these systems requires a symbolic representation of knowledge, yet not all design knowledge can be easily formalized and inserted into a knowledge base
- even in cases where the design knowledge can be formalized and captured within symbolic descriptions, it is a time-costly task, which requires the allocation of sufficient resources. Additionally, knowledge is often domain specific, which dramatically reduces its usability in future systems, which are of a different domain

Considering these limitations and others, as well as the development of neural-network technologies in artificial intelligence, a new approach to developing computational design systems has gradually emerged. Instead of relying on symbolic descriptions, new systems which utilize sub-symbolic descriptions are being developed, by using artificial neural networks. Interesting examples for such systems, which have achieved success in coping with previously-considered difficult tasks, are reviewed below.

First, many of the neural-network based computational design systems target the quick evaluation of design solutions at the initial stage, in order to both shorten conceptual design processes and aid in making sound decisions, at this critical phase. Various examples for such systems are introduced here. Singaravel and Geyer, for example, have proposed a deep learning method for estimation of thermal energy levels during the early stages of the design, which is both accurate and significantly faster than existing simulation models (by a factor of ~260). By shortening the traditional time-costly simulation process, they enhance our decision making capabilities at the early design stage[40] (Singaravel & Philipp, 2018). Sharing

[40] These are of high importance, since often have a great impact the final design.

this aim, McComb has proposed a method for utilizing auto-encoders to enable fast evaluation of engineered systems, demonstrated in the context of offshore structure engineering (McComb, 2018).

Researches have also found a certain type of networks, termed "fuzzy neural networks", to be useful in striving toward the above aim. For example, Huang et al. have developed a computational method for evaluating different design solutions at the conceptual design stage, by combining a fuzzy neural network with a generative algorithm. They have used these networks for evaluating design solutions in cases where the description of evaluation criteria is imprecise (for example, in qualitative cases relying on linguistics variables) (Huang, Liu, Li, Xue, & Wang, 2013). Sun et al. have also utilized a fuzzy neural network for identifying promising candidate design solutions at the conceptual design stage, implemented in the context of designing mechanical parts for mountain bikes. Their model suggested a way to convert customer needs into quantifiable attributes, which can then be used to automatically evaluate potential design solutions, reducing the burdens of translating needs into requirements and searching through the solution space for suitable candidates (Sun, Kalenchuk, Xue, & Gu, 2000).

Furthermore, Eisenhard et al. have proposed a model for evaluating the impact of candidate design solutions on the environment, at the conceptual design stage. Their work aims to improve conceptual design processes by enabling the early integration of life-cycle assessment, which is highly-time consuming, via approximating it to a satisfactory level. Their usage of a neural network which learns from data of existing products (regarding energy consumption during their life-cycle) has enabled to predict the potential impact of new designs on the environment (Eisenhard & De Schepper, 2000). Additionally, in the complex field of mechatronics, Mohebbi et al. have proposed a model for evaluating system designs at the conceptual stage. They have used a Choquet neural network to deal with the problem of decision making under difficult circumstances, i.e. in multi-objective problems where multiple interacting criteria should be addressed. They have demonstrated a systematic approach for dealing with such problems in engineering, which can facilitate efficient evaluation of concepts at the conceptual design stage (Mohebbi, Baron, Achiche, & Birglen, 2014).

Another potential use of neural-network based computational design system is the generation of design candidates, fulfilling sets of requirements. For example, Zhang et al. Have developed a model for generating candidate forms fulfilling a set of desired requirements, by learning from a database of existing designs (in this case, of past airplane models). The applicability of their model was demonstrated using a case study of glider design in the field of aeronautical engineering, by combining a variational auto-encoder-decoder and a genetic optimization algorithm (W. Zhang et al., 2019).

The two above approaches (of identifying candidate solutions and generating ones) were integrated to produce systems for joint generation and evaluation of candidate solutions. A prominent example is the system by Hsiao and Tsai, which integrates a fuzzy neural network with a genetic algorithm for evaluation and generation of design solutions at the conceptual design stage. Their model, which was demonstrated using a case study of a door-lock mechanism design, establishes a relation between a product's image and certain parameters defining its form. The result is that users engaging in conceptual design can both match a given form with a linguistic description and search for other forms, which satisfy the initial parameters but better match the descriptions (Hsiao & Tsai, 2005).

Researches have also attempted to streamline the initial design process, by supplying designers with automatic means of translating initial requirements into formal descriptions, that can then be understood by a computational system. Kim et al. Have developed a concept for a virtual assistant for supporting design processes, using deep learning techniques. Specifically, they have implemented a computational system, based on an auto-encoder, which can extract functional requirements from descriptions given in natural language (Kim et al., 2019). Facilitating human-machine communication in this manner can improve conceptual design processes, by reducing the time spent to explicate the design requirements in a formal and rigorous manner, to be input to the computational design system.

Finally, few systems were developed using neural network technology which support conceptual design from the perspective of design cognition. An example which is important for our work is the system by Karimi et al., which has demonstrated the potential of deep learning to assist with conceptual shifts in design. Their system consists of a convolutional neural- network-based agent which can propose alternative interpretation for designers' sketches (Karimi, Grace, David, & Lou Maher, 2018). Such systems may be integrated into current CAD systems, to enhance the designer's ability to re-conceive of the design, by providing opportunities for shifting their current view. In addition, though not a neural-network based system, we would like to mention the work by Yumer et al., who have designed a model for numerically learning semantic attributes of 3D forms, based on a crowd-sourced database. Their work demonstrates the possibility of teaching a computational system to recognize visual attributes which the designer may associate with the artifact, and therefore relevant for interpretation activity (Yumer et al., 2015).

2.4.3 Neuro-Symbolic Integration & the Unfulfilled Potential in High-level Tasks

The previous dominant approaches to constructing design systems[41] can be seen as important representative members of two opposing approaches for the study of cognition, and accordingly to AI, commonly referred to as "symbolicism" and "connectionism" (Hilario, 1995).

[41] Knowledge-based vs. neural-network based.

The first equates cognitive processing with the manipulation of symbolic structures, and accordingly emphasizes the syntax and semantics which are involved in thinking activity. The second views cognition as a sub-symbolic tuning of pattern-recognition mechanisms, which in-themselves do not require any explicit symbolic representation.

Acknowledging the strengths and weaknesses of each of the above resulted in an integrated approach called "hybrid systems". [42] These systems draw on the strengths of each approach for creating synergistic models, which can tackle difficult tasks in AI. While examples in design are not as abundant as in other fields, we review selected systems which aid in grasping their potential for the future development of computational system in our field.

First, shortly after its inception, researches have observed the potential of neuro-symbolic integration for improving the intelligibility of neural-network-based artificial intelligence systems. Summers and Dybowski have proposed to use a hybrid system for automated medical evaluation, with the aim of rendering computation activity itself more intelligible (which is important for medical professionals, in order to be able to trust the system's judgment). Their model utilized the non-linear (and therefore flexible) properties of neural networks along with the explicit representation capabilities of uncertain situations via causal probabilistic networks, rendering the system as a "grey-box", i.e. partially transparent, instead of the common neural network black-box (Summers & Dybowski, 1994). Such efforts have led to the development of the sub-field of "explainable artificial intelligence". An interesting example for such system can be seen in the work by Daniels et al., which attempts to explain deep neural networks using knowledge (Daniels, Frank, Menart, Raymer, & Hitzler, 2020).

Second, neuro-symbolic systems have demonstrated a strong capability in tasks involving classification, outperforming their non-hybrid state-of-the-art predecessors in certain cases. An interesting example can be found in Chen and Liu, who have proposed a neuro-symbolic model for visual recognition of emergent two-dimensional shapes. They have integrated two neural networks with a mediating symbolic component, forming a three-layered feature-based hybrid system. As opposed to previous non-hybrid systems, their system enabled to detect sub-shapes even in cases of uncertainty or incompleteness of the visual data used as input (Chen & Liu, 1996). Similarly, Sanchez et al. have applied neuro-symbolic integration for the visual inspection of artificial textures, by combining expert knowledge with a classification system. Their system achieved higher accuracy rates, in comparison with existing non-hybrid systems (Sánchez, Vergara, Salgado, & Domínguez, 2011). In another classification task, researches have demonstrated the ability of hybrid systems to

[42] Also referred to as "neuro-symbolic systems".

automatically reason with respect to qualitative states, which characterize medical diagnosis (Tan, Hayes, & Shaw, 1996).

Finally, it was recently demonstrated that neuro-symbolic systems can aid in elucidating the internal structure of complex data structures. One example is the work by Sarkar et al., who have utilized neuro-symbolic integration for detection of instabilities in combustion engines. Their model included a convolutional neural network, which extracts semantic features from high-speed camera video, with a symbolic time series analysis component, which enabled to capture the manner in which these features change over time (Sarkar, Lore, & Sarkar, 2015).

Considering the above, it is no wonder that many researches see the neuro-symbolic approach as highly promising for the construction of intelligent computational systems (for example: Garcez, Broda, & Gabbay, 2002; Kühnberger et al., 2007; Ma, Francis, Lu, Nyberg, & Oltramari, 2019; Mao, Gan, Kohli, Tenenbaum, & Wu, 2019). Their future development, however, entails many challenges. As explained by Lamb, one of the main challenges for their development is the need for a semantic foundation, as a basis for neural-symbolic computation (Lamb, 2008). Since we do not have a denotational semantics for these computational models, and despite the fact that research on the topic has existed for some time now (for example Taha & Ghosh, 1999), bridging connectionist networks and symbolic descriptions remains a difficult task. This needs to be considered in our later discussion of computational systems for interpretation in design.

2.4.4 Boundary of Current Approaches

This section has surveyed various approaches for the development of intelligent systems, which can potentially serve as the basis for computational systems for interpretation in conceptual design. In this, we have introduced exemplary implementations and discussed their strengths and weaknesses. We conclude by further outlining the capacity of current knowledge to facilitate the development of intelligent systems specifically for conducting interpretation in conceptual design, in accordance with the aim of this work:

With respect to support systems targeting interpretation of structure in conceptual design activity, current state-of-the-art work enables us to:

- automatically detect various sub-shapes within a two-dimensional configuration of larger shapes, based on visual input and a supporting knowledge-base (which is useful for informing CAD systems regarding the potential visual interpretation of the designer regarding the geometry which is represented)
- automatically match three-dimensional forms with semantic attributes (enabling to inform the CAD system of the manner in which the designer views the object on a conceptual level)

- automatically propose various interpretations to two-dimensional shapes, by an analogy-based mechanism, drawing on an image knowledge-base (enabling the CAD system to encourage conceptual shifts during conceptual design activity, by drawing the designer's attention to new interpretations)

On the basis of the above, we identify the specific limitations of existing work, which are directly addressed by our work:

- With respect with the types of interpretations handled by the computational system, current state-of-the-art systems largely rely either on a statistical attribution of a description to a structure, or on identifying an analogical mapping. However, they generally do not address metaphoric interpretation. This is mainly due to a lack of a suitable knowledge representation framework.

- Even in the few cases where metaphoric attributes are automatically associated with the structure (for example in Yumer et al., 2015), current interpretation by computational systems is done on the basis of direct matching of the structure with a symbolic description. Unlike in real-world conceptual design, these symbolic descriptions do not have an internal structure. In our work, we propose an ontology for such a structure, which enables a richer representation of interpretations in a symbolic manner, within the knowledge base. This also facilitates the utilization of automated reasoning with respect to interpretations, within the computational system.

2.5 From Symbols and Metaphors to Worlds

2.5.1 Interpretation and Signification

Before we approach the topic of metaphor, which is important for our inquiry into interpretation, we provide a basic semiotic background, which aids in understanding some fundamental aspects of signification. This is important since, as metaphors of the kind we are interested are used to speak of one object as another, they necessarily point beyond the object itself. We thus briefly review Charles Sanders Peirce's account of signification, which is widely accepted as a theoretical foundation in this field.

Peirce's notion of sign is elaborated in a triadic model.[43] In this model, signification occurs as a relation between the following three components: an object (which is referenced or pointed to in some manner), a representamen (a thing representing the object), and an interpretant

[43] As opposed to the dyadic model of de-Saussure (1959).

(its effect on the interpreting agent or "the idea to which it gives rise" ;Mohanty, 1997) (Peirce, 1998, p.477).

Further, he suggests three main forms of signification, i.e. of manners in which a sign can stand for an object: symbolically, indexically and iconically. In accordance with these, he suggests three categories for classifying signs: symbol, index and icon. Symbols are signs in which the relation between the object and representamen has been established as a convention, without an inherent necessity (consider for example the relation between the number two and the character "2", which has been arbitrarily assigned to represent it). When there exists a natural relation between the two, the sign might be regarded as an index (as in the case where we see smoke, which signifies the potential existence of fire in its vicinity). Finally, icons are characterized by a relation of similarity in form between the object and the representamen. The representamen somehow embodies a part of the object, in this way or another, or "exhibits" it (Burks, 1949) (consider the famous "smiley" icon which structurally and visually resembles a human face, on an abstract level).

In this work, acts in which designers let one object stand for another during interpretation activity are regarded as the formation of sign in-action, which can be generally regarded as symbols (due to the ad-hoc nature between the structure and its interpretation). However, such signs are also often also iconic (owing to the frequent occurrence of similarity between the structure and the referent in the interpretation).

2.5.2 Metaphor: a Wondrous Scandal

Few other linguistic phenomena have received such attention, and have posed such tremendous difficulties, as that of metaphor. Expressing this fact, Umberto Eco has stated that metaphor "defies every encyclopedic entry" (Eco & Paci, 1983, p.217). From Eco's perspective, metaphors are seen as a "scandal" in use of language, a human deviation from the linguistic infrastructure which facilitates and enables communication. With all the difficulties inherent in its study, we believe that research into interpretation must address the notion of metaphor, owing to its centrality for high-level cognitive abilities, as discussed hereafter.

We are most interested in the account of conceptual metaphors as powerful cognitive devices, given by Lakoff and Johnson. In their important work "Metaphors we Live by", they explain their view of metaphor as a tool for utilizing knowledge from one domain (source) via its projection onto another domain, which is less understood (target). Using the famous example of "time is money", they demonstrate how a highly abstract concept (time) can be understood in terms of a more concrete concept (money), which we can grasp rather firmly. The emphasis here is neither on metaphors as mere decorative literary devices, nor as ones of communication (as in speech-act theory), but rather as ones which facilitate thinking and

reasoning (Lakoff & Johnson, 2003). From this aspect, we can begin to relate metaphor with interpretation in design.

How do metaphors function in design? As mentioned by Casakin, despite their centrality to human life and communication, few studies have empirically examined the use of metaphors in design practices, and the manner in which they function in design (Casakin, 2006). Nonetheless, certain fundamental aspects of their contribution as cognitive tools for design have been laid out. Casakin has explained that metaphors are frequently used by designers in the act of encoding complex systems of relations as short verbal descriptions, which can be intuitively understood. To this, Hey et al. have added that, by utilizing metaphoric descriptions during the design process, designers are able to gradually develop a high-level, conceptual understanding of the task at hand (Hey, Linsey, Agogino, & Wood, 2008).

Considering both of the above, we can start to delineate the role of metaphor within the context of interpretation activity. When designers see an object as another, and assign it with a metaphoric description accordingly, they may begin to form an abstract conceptual understanding, which aids them in their interaction with structure. We thus approach metaphoric description as a form of high-level control, which utilizes interpretation for structuring the agent's understanding, and thereby shaping subsequent action.

2.5.3 Metaphor and Computation

Perhaps one of the best systematic accounts of the problem of metaphor is provided to us by Searle, who has made an effort to elucidate it from the perspective of speech acts and communication. We open this sub-section by briefly reviewing the work by Searle on this matter, as a theoretical foundation for approaching the notion of metaphor from a computational perspective. Searle starts by making a fundamental distinction between "sentence meaning" and "speaker meaning" (Searle, 1990). Sentence meaning refers to the literal meaning of the uttered words, while speaker meaning refers to their indented meaning (also called utterance meaning). He further explains that metaphoric meaning coincides with speaker meaning.

Somewhat in correspondence with Eco's "scandal", Searle construes the problem of metaphor as follows: "The problem of explaining how metaphors work is a special case of the general problem of explaining how speaker meaning and sentence meaning come apart" (Searle, 1990, p408). This question is further elaborated in the following form: suppose a speaker says the sentence S, which literally means R, but metaphorically means P. First, how can we know that S does not mean R, and second, how can we compute P. While answering the first may not seems difficult (i.e. we only need to know if the sentence should or should not be taken literally), the second poses a significant challenge.

As a partial answer to the second part of the question, Searle provides us with a set of principles which enable to explain the relation between P and R under certain circumstances. One example which can be given is the following principle: “things which are P are often said or believed to be R”. Applying this rule, for example, we can take the sentence “he runs like a turtle”, and deduce the sentence “he runs slow”, since turtles are commonly seen as slow.

Searle’s structuring of the problem, as well as his proposed principles, are an important contribution for establishing a systematic account of understanding metaphor. However, two main limitations should be mentioned. First, the proposed principles are generally useful for supporting search processes which take utterances as input and provide speaker meaning as output. Yet, they do not explain how to compute specific values. Even if we were to use probability to choose between multiple candidates, there still remains the problem of changing contexts which may significantly alter the intended meaning. Second, as mentioned by Searle, these principles are by no means exhaustive, so that identifying and elaborating additional principles is necessary. Nonetheless, Searle’s account provides us with a strong foundation for approaching metaphor from a computational perspective.

Considering the size of the problem and its centrality to understanding natural language, it is not surprising that many researches strive to develop computational systems for dealing with metaphor. Such systems can be roughly divided into four main categories: extraction, comprehension, generation and reasoning. We review several major works in each category, in order to facilitate an understanding of our current computational capabilities in this field, and their relevance for this work.

With respect to metaphor extraction systems, an important example is provided by Mason, who has demonstrated the possibility of extracting metaphors from textual data (Mason, 2004). One of the main advantages of this system lies in the fact that, while other systems usually deal with a very limited set of manually constructed examples, it draws directly on a substantial existing database (WordNet). Such systems can be used for facilitating a rich database of metaphors in a semi-automatic manner.

Systems capable of generating metaphoric expressions have existed for some time now, and can be traced back, to the best of our knowledge, as far as the 1980’s. One such example is the work by Young, in which the possibility of utilizing a relational database for metaphor generation has been shown (Young, 1987). In a more recent example, the system by Abe et al. has demonstrated how metaphors can be automatically generated based on statistical analysis of co-occurrence relationships between words, further validated using evaluation of human subjects (Abe, Sakamoto, & Nakagawa, 2006). Work on metaphor thus enables, to a certain extent, to computationally form metaphoric expressions, which may be useful for

design agents concerned with tasks of assigning interpretations, in the form of symbolic descriptions.

Comprehension systems attempt to automatically interpret given utterances. For example, Kintsch has demonstrated the possibility of computing reasonable interpretations of metaphors, by representing meaning using vectors in a high-dimensional semantic space (Kintsch, 2000). More recently, focusing on pragmatic aspects of understanding metaphorical utterances, researchers have proposed a computational model which not only suggests plausible metaphorical interpretations, as in the above case, but also enables to evaluate whether certain features are likely to be attributed to the entities referred to in the metaphor (Kao, Bergen, & Goodman, 2014). Such work is useful for supporting metaphor-based reasoning, by extending a single metaphoric interpretation into set of attributes which may serve as a basis for a more elaborate interpretation of the design (see further regarding reasoning).

With respect to reasoning systems utilizing metaphoric expressions, an interesting example is the work by Narayanan, which has demonstrated the possibility of automated reasoning based on metaphorical utterances. In this work, paper articles from different domains were parsed and fed as input into the system, which could draw sensible inferences based on metaphorical expressions in the article (Narayanan, 1999). Such systems support our hypothesis that, given a knowledge representation framework for interpretation of structure in design, creating a computational system for interpretation in action, which automatically reasons about the design, is a feasible task.

2.5.4 Worldmaking as a Linguistic Act

This sub section has introduced two notions, which are important for this research, from the fields of semiotics and cognitive linguistics: signification and metaphors as cognitive devices, respectively. We now conclude this part by relating them within a larger notion of worlds, which may be facilitated by them.

The American philosopher Nelson Goodman has rightfully claimed that we, as people, are world makers. Our symbolic systems of language enable us to form myriad worlds, which serve as our constructed, yet nonetheless actual, realities (Goodman, 1978). Focusing on Goodman's fundamental claim, regarding the manner in which symbols constitute worlds, we may begin to tie it with interpretation activity, using the notions mentioned above.

When designers see one object as another and interpret it accordingly, they do this by assigning a symbolic description to the object. For example, if I see a cardboard box as a building, I am (even if implicitly) assigning the box with the symbolic description of "building". Notice that, by doing so, I have formed a sign. In this specific case the sign is both

symbolic (I have arbitrarily assigned it) and perhaps iconic (in the sense that the form of the box may be reminiscent of a building). Now imagine that another box stands beside the first one. If I choose to extend my interpretation to the second box, we can say that I am now "seeing" two buildings. This interpretation may further lead me to conceive of the buildings as a "small neighborhood" or as a "city street". By further extending my interpretation, I can start to form an interpretive world, within which the previous symbolic descriptions are further attributed with meaning. This world can also serve as a general context for assigning further interpretations (for example, in the case of a "city", I could add a green object representing a "park").

Our key point in the above example is that, while interpretation may begin by assigning objects with symbolic descriptions, these descriptions may be further elaborated into symbol systems forming virtual interpretive worlds. Therefore, we should be aware that designers do not only assign disparate interpretations, they also make cohesive worlds from them. This point is explored in the later part of the work (chapter 7), focusing on the manner in which several interpretations can be joined to form larger wholes. Finally, it is important to notice that the whole process of interpretation, as construed here, relies heavily on metaphor. By its virtue, we freely and intuitively move from the concrete to the abstract and back, as interpreters and world makers.

2.6 JRG as a Case Study for Interpretation in Conceptual Design

To collect empirical data of design activity, as a basis for our inquiry into interpretation, we have chosen to focus on the practice of JRGs, as a case study. Our choice is justified later in this section. First, we briefly introduce the practice of JRGs, and provide the necessary general background in a concise manner. We then attend to a specific aspect which is highly relevant to our work - the use of rocks as representational devices.

2.6.1 Traditional JRG design

JRGs have long existed as an art form and a design practice. The classical traditional manual "Sakuteiki" (translated in Takei & Keane, 2001), which had first outlined their design guidelines in a written form, dates back as far as a millennium, and consists mainly of textual information. Later important works such as the "Illustrations" (translated in Slawson & Zoὶen, 1991), which can be traced back to the 15th century, offer graphic material which can complement the former, and therefore facilitate a deeper understanding of this practice.

While different styles are associated with different visual expressions, several major principles can be mentioned as foundational, if not essential:

- **frugality:** usage of a small number of elements
- **abstractness:** their design generally refrains from detailed figurative expression
- **representational quality:** elements are commonly assigned with metaphoric interpretations
- **asymmetry:** forms are commonly organized in space as to avoid regularity or symmetry
- **consideration of viewpoint:** the various positions users may assume via movement through the space guide their visual and spatial organization

As a preparation for the project, we have studied both of the classical manuals mentioned above, with the aim of understanding the guiding principles of the traditional design methodology. This greatly inspired our work, and invited us to deeply inquire into interpretation practices in design. The main principles that contributed to the work are integrated relevant throughout the dissertation, as needed. However, it seems necessary at this point to mention the central principle, which underlies our approach. Reading the Sakuteiki, we find the following words already in the second instruction, immediately following an explanation regarding carrying stones to the site:

> *"Choose a particularly splendid stone and set it as the Main stone…following the request of the first stone, set others accordingly" (Takei & Keane, 2001, p.181).*

By reading this instruction carefully, a door to a world of interpretation opens. The designer is instructed to first select a rock which he finds "particularly splendid", and then "listen" to it and add rocks accordingly. What is a splendid stone? How should one listen? Right from the start, the manual encourages the designer to approach the design and these guidelines as an active interpreter. For this reason, and many others, we have found great potential in utilizing JRGD as our case study of choice.

2.6.2 Interpretation in Traditional JRG

JRGD is well known for its extensive use of metaphoric interpretations, both in the design process itself and for describing the final product of the design, as explained hereafter (Fig. 2-5). This ranges from assigning names to preferable rock forms or specific rocks in a composition (a), and up to forming narratives which encompass a full garden, as in the garden of Ryōan-ji (c). It is important to note that these names are not regarded as mere decorative linguistic elements attached to the artifact. Rather they are used to speak of it metaphorically, as to expose or emphasize certain visual features, in an intuitive manner. Form and position

are thus tied with meaning, by such interpretive acts (Nakagawara, 2004; Slawson & Zoìen, 1991). As such, this practice is highly relevant for our inquiry into visual interpretation of design elements, and serves as an endless source of knowledge and inspiration.

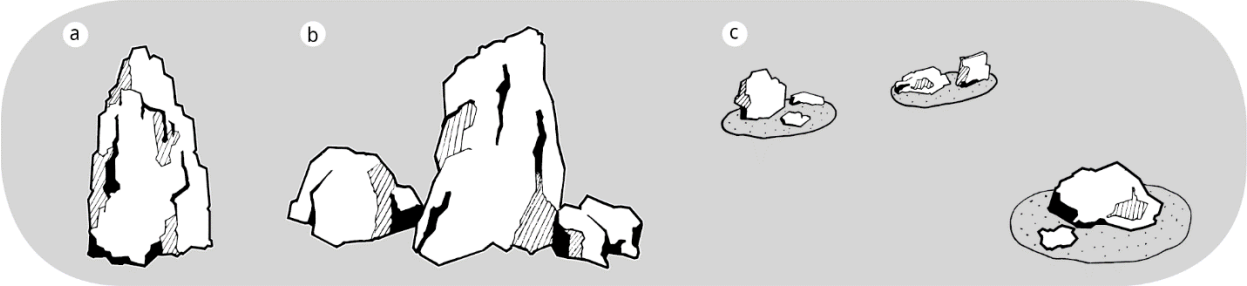

Figure 2-5 Interpretation in JRGD: (a) "heroic rock"; the rock receives its name on the basis of certain visual qualities, such as massiveness, texture direction etc., associated with it; reproduced from (Slawson & Zoìen, 1991); (b) "Teacher and Student" or "Buddhist Triad" composition, the middle rock is assigned with a role of teacher or Buddha and the other two its disciples, Daitoku-Ji, Kyoto (Mansfield & Richie, 2009); (c) A part of the rock composition at the garden of Ryōan-ji in Kyoto, commonly interpreted as "a tiger carrying its cubs across a river" (Yamada, 2009).

2.6.3 Further Considerations in Choosing JRG as a Case Study

Aside from the tight link with the activity of interpretation via metaphoric descriptions, additional considerations support the choice of JRGD to serve as our case study. We lay out our main considerations and rationale for this choice below.

Generally speaking, the need for empirical data for studying the activity of interpretation as a human ability is undeniable. The question is thus, if we are to collect data of conceptual design activity, what kind of data can best aid in our inquiry? As said by Minsky: "for me and a whole generation of students, the world of work with children's blocks has been the prism and the pendulum (referring to Galileo & Newton) for studying intelligence" (Minsky, 1986, p20). We therefore need to choose our "children's blocks", that will be best suited for our inquiry. Several guidelines can be outlined as follows: (1) the documented activity should be one of a conceptual design process; (2) the task should contain elements which are ambiguous (to offer enough opportunities for interpretation); (3) the task should be simple enough to afford a deep analysis, in order for us to avoid over-complex situations, which will obscure the basic mechanisms that are at play (as reflected in Minsky's comment above); (4) the task should naturally accommodate the notion of representational interpretation.

In accordance with these, we have found JRGD as a suitable design context for our study, since it: (1) can easily serve as the basis for a conceptual design task which does not impede creativity due to the burdens of technical requirements; (2) mainly consists of ambiguous elements, and tends to avoid explicit figurative representation. Additionally, its elements are less-abstract than simple blocks (commonly used in "block worlds" in AI) so that

interpretation is easily invoked by them; (3) can be conducted with a set of simple elements which need not be divided or altered (and therefore serve as relatively-manageable environment for the exploration of interpretation in-action; literally a "sand box" task); ;(4) already has the aspect of representational interpretation integrated into the design process (as previously explained).

2.6.4 Focusing on Rocks as Key Design Elements

Japanese gardens consist of a relatively small number of elements. Among these are: rocks, moss, gravel, small plants and others. While each contributes to the experience of the garden, and of course to its interpretation, we have resolved to isolate the garden rocks as our target of inquiry. Note that, even with other elements removed from consideration, their range of expression, and thus of interpretation, is inconceivably broad. Furthermore, this approach is in-line with the guidelines provided in the classical manuals, which clarify that rocks are the main element in traditional gardens, and serve as the foundation for the rest of the design. In fact, the Sakuteiki opens with the words "The art of setting stones"[44], which clearly reflects its position towards the importance of rocks, as opposed to other elements. We do keep in mind the need for a future extension of our scope to include other design elements in our tasks and in their analysis.

[44] (Takei & Keane, 2001); notice that, in this work, the words "rock" and "stone" are used interchangeably.

Chapter 3 Methodology

This research deals with an intricate aspect of the human mind - our cognitive ability to engage in interpretation. In accord with current cognitive sciences, we adopt the computational-representational view of mind, which generally assumes that the existence of mental representations and computational processes operating on them, can together account for human cognitive activity (Thagard, 2005). Taking this perspective, we draw fundamental guidelines, which shape our methodological approach, as follows:

First, rather than attempting to replicate the exact internal mechanism responsible for our interpretation capability, we humbly aim to model it, by identifying its essential representational and computational components.[45]

Second, and considering the above aim, we take the constructive research approach. This approach, which draws on pragmatist views, utilizes theory for solving practical problems, by forming new artifacts (Crnkovic, 2010). Our desired artifact (i.e. our model for interpretation) will ideally harness existing knowledge from multiple relevant disciplines to answer our research question. To recapitulate:

> ***How can we deepen our understanding of representational interpretation (RI) of structures in conceptual design, to both enhance computational design systems and extend our knowledge of human cognition?***

A concise description of the phases in constructive research can be found in Lehtiranta et al., as follows: (1) problem-definition, (2) pre-analysis, (3) construct-design, (4) demonstration of feasibility, (5) clarification of relation to theory, and (6) examination of generalizability (Lehtiranta, Junnonen, Kärnä, & Pekuri, 2015). These have guided us in setting the framework for our research methodology, presented in general outlines in Figure 3-1. In the following sub-sections, we further elaborate on several of these building blocks, to form a clear picture of how this work was structured and conducted.

45 Considering that "All models are wrong, but some are useful"; a quote commonly attributed to George Box (1979).

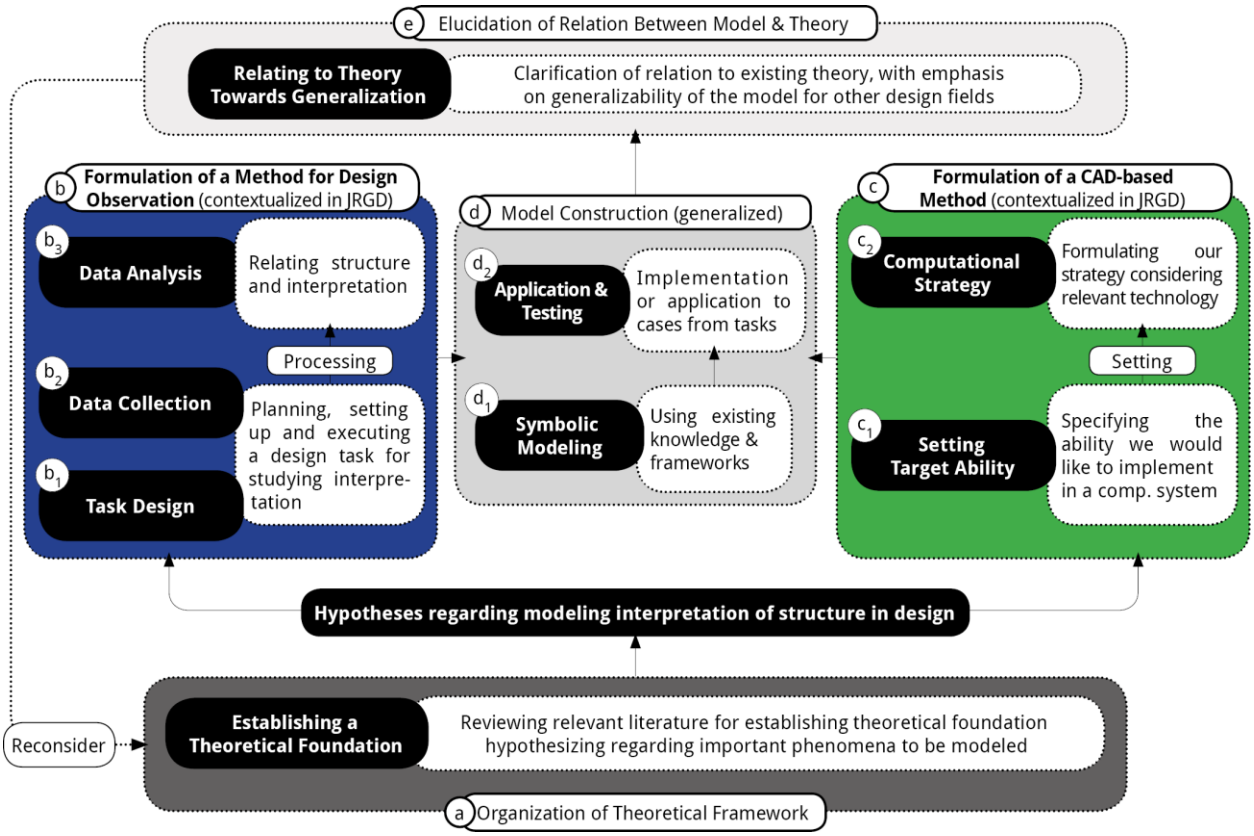

Figure 3-1 Outline of our research methodology.

Finally, it is worth noting that our methodology for studying human cognition aligns with foundational works in artificial intelligence[46], in several key aspects, such as our focus on performance (rather than development or learning), and our approach to cognition as an act of manipulating symbolic descriptions. While these foundational works have been superseded by utilizing new methods etc., they have successfully carved out an essential aspect of cognition as an object of study, i.e. our symbolic capacities. As such, they remain relevant and important as a guiding light for current studies in the field.

The following sections introduce the key knowledge-domains on which we draw in this research, as well as the two methods which are integrated in this work, for inquiring into interpretation - that of utilizing computational systems and that of using empirical data (see Figure 3-1 above; b, c). These are followed by introducing our general modeling approach and the way it relates to existing theory (Figure 3-1; d, e).

[46] Such as the notable "Human Problem Solving" by (Newell & Simon, 1972).

3.1 Organizing the Theoretical Framework

Our theoretical framework is based on several domains of knowledge. The main categories and major sources within each category are:

- **philosophical foundations:** these are mainly set in the philosophy of mind (Searle, 2004) and constructivism (Goodman, 1978)
- **knowledge of cognitive science:** focusing on cognition as a situated phenomenon (Clancey, 1997; Clark, 1998; Robbins & Aydede, 2009; R. A. Wilson & Clark, 2009)
- **knowledge of state-of-the-art AI systems:** in this, we focus on systems for supporting interpretation activity in conceptual design, as in Karimi et al. (2018)
- **models for design as a situated activity:** we rely on existing models which provide us an understanding of design activity from a computational perspective. The main model utilized in this research in the situated Function-Behavior-Structure framework (Gero & Kannengiesser, 2004)
- **knowledge of key aspects of interpretation activity**: existing research of interpretation in design generally offers us insights into interpretive practices from a qualitative perspective. Accordingly, it is mainly available as descriptions of various phenomena that illuminate aspects of interpretation processes in design (Goldschmidt, 1988; Schön & Wiggins, 1992)
- **knowledge of relevant cognitive mechanisms:** key examples are analogy as a tool for mapping between different domains (Gentner, 1983; Gentner & Smith, 2012; Holyoak & Thagard, 1996) and metaphor as a cognitive device for establishing high-level conceptual understanding of the world (Lakoff & Johnson, 2003)
- **domain specific knowledge of JRGD:** the traditional manuals serve as a rich source of insight for approaching design as an activity of interpretation (Slawson & Zoȉen, 1991; Takei & Keane, 2001)

3.2 From CAD to Cognition

As previously mentioned, current approaches to the study of human thinking in cognitive science are based on the "computational-representational understanding of mind" (Thagard, 2005). The core of this view is that human cognition can be described as an activity of computation, which involves representations (knowledge) and computational processes

operating on these. By this view, in order to understand interpretation activity, it is essential to be able to describe the knowledge involved in it, as well as the processes which operate on this knowledge in a computational form. Consequently, computational implementation is widely accepted as a valid means in cognitive science for testing hypotheses regarding the workings of mental phenomena (Friedenberg & Silverman, 2006). In accordance with this approach, we harness Computer-Aided Design (CAD) systems, as a computational environment for implementing and testing our insights. It is worth noting that such implementations are not expected to replicate the cognitive mechanism which is being studied, but the behavior which it produces.

Furthermore, when discussing knowledge representation in Chapter 2, we have explained that this work chiefly deals with knowledge in symbolic form. In this we rely on the "Physical Symbol System" Hypothesis" (Newell, 1980). This hypothesis regards human cognition as an activity of symbol manipulation. Despite many attacks from various perspective, it is fair to say that the hypothesis still stands (Nilsson, 2007). Accordingly, our efforts are directed at capturing the knowledge and processes involved in interpretation activity, using symbolic means of representation.

3.3 Drawing on Empirical Data

As a powerful means for getting insight into design activity, we have resolve to collect and analyze empirical data from design activity. This demanded us to contextualize the work, via focusing on a certain design practice, as a case study. The chosen design practice was expected to encourage the natural occurrence of interpretation during design activity, in a manner which is frequent enough and clearly observable to allow analysis. Acknowledging the tight relation between traditional practices of JRGD and interpretation, as we have construed it, the choice of theses gardens[47] seemed natural and promising. Already in the early phases of the research, we have discovered that this initial (and rather intuitive) choice offered many advantages for the study of interpretation.[48]

3.3.2 Our Design Task

We provide an overview of the task we have formulated for studying interpretation activity. Further details regarding setup, participant selection etc., as well as procedures for data processing and analysis, are provided in chapters 6 and 7, which employ this method.[49]

[47] As a design context, this can be further characterized as a special form of architectural or landscape design.
[48] The choice of this practice is further elaborated and justified in Chapter 2.
[49] See 6.4 and 7.3, accordingly.

We have planned and executed a conceptual design task, focusing on the design of a miniature JRG, using a table-sized model (Figure 3-2). The task was conducted in two different cycles: first, with individual designers and second, with designers working in pairs. The designers were requested to design a "garden", and were free to interpret the task within certain limits (read further in 6.4 and 7.3). The "design site" consisted of a wooden tray covered with a thin bed of white sand, placed on a desk in front of the participants (Figure 3-2). As design materials, we have supplied the participants with a small yet varied collection of rocks, in different forms, sizes and textures. The subjects were directed to design within the tray's limits, and to not stack rocks on top of other rocks, in order to maintain the fundamental and essential guidelines of traditional practices.[50]

Within the above constraints, the design task offered ample room for interpretation by the subjects regarding the idea of a "garden" etc.[51] The subjects were thus expected to both construe the problem and solve it, by utilizing the design materials available to them, in accordance with their construal of the task.

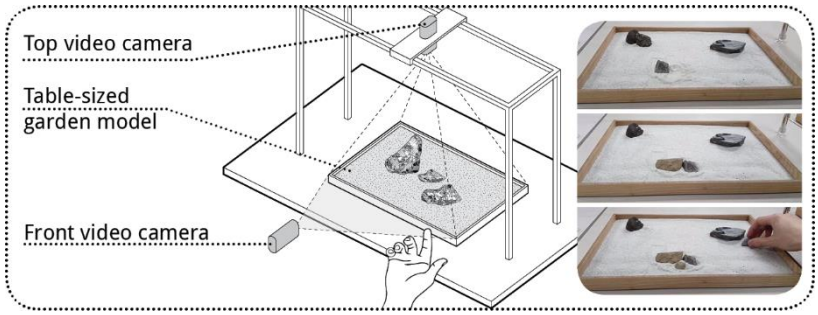

Figure 3-2 Our design task for studying interpretation activity in the context of JRGD

3.3.3 Protocols as Sources of Data

With the aim of establishing rich design protocols (ideally carrying important information regarding interpretation processes), we requested our subjects to design in a "think aloud" style, i.e. to voice out their internal dialogue (Charters, 2003; Ericsson & Simon, 1980). This is, of course, a common practice in studies of interpretation (see Goldschmidt, 1991; Gürer et al., 2014; Schön & Wiggins, 1992; Suwa, 2003). The audio data collected during all sessions consisted mainly of participants' utterances, which accompanied the design session.

[50] As indicated in the notable JRGD manual "Sakuteiki" (Takei & Keane, 2001).
[51] See the related work by Goldschmidt, in which subjects were asked to design a "cube" house (Goldschmidt, 1988).

3.4 Modeling Interpretation Activity

In the absence of a model for interpretation of structure, modeling in this work essentially means, first and foremost, identifying and naming entities which are fundamental for this activity, and second, the identification of relations between them. This is done via analyzing our empirical data from design activity, and attempting to account for interpretation of structure clearly and coherently, so that it may be formalized into a computational model.

Furthermore, as an integral part of the work, we have continuously placed new terms, definitions and components of RI activity within the context of existing models in design theory. As previously explained, Gero and Kannengiesser's situated FBS framework[52] served as a main conceptual holding environment for the entities of our model. Additionally, considering the tight relation of "seeing-as" practices with analogy, we also draw on the earlier model by Qian and Gero, which attempted to formalize analogy-based design (Qian & Gero, 1996).

This helped in clarifying how the newly proposed entities fit within our current understanding of the nature of design activity, especially with respect to well-accepted models and theoretical notions which are central to our inquiry.

[52] In (Gero & Kannengiesser, 2004); refer back to 2.2.3.

Chapter 4 Approaching the Study of Interpretation of Structure: A Case Study of RI in JRGs[53]

This chapter asks the following question: how can we approach the modeling of RI activity? To answer this question, we attempt to establish a basic thought-framework for this practice, by defining a set of concepts which are necessary for relating structures with interpretations. These concepts include an original notion that we term as "complementary visual potential" - a property which ties the elements of the structure with their metaphoric interpretation. On the basis of these, we propose, implement and test a computational framework for relating structures with interpretations, in the context of JRGD. Testing is done by attempting to generate alternative designs for an existing rock composition in the famous garden of Ryōan-ji, via assigning the structure (i.e. the rocks) with different metaphoric interpretations. The framework demonstrates how simple spatial configurations may emerge from different interpretations. This renders it as a springboard towards systematically describing the practice of interpretation of structure.

4.1 Introduction

How do designers attribute structures with metaphoric descriptions? We approach the task of formalizing this practice by studying it in the context of traditional JRGD, and the way in which metaphors may guide the design process of rock compositions.

Metaphors are powerful cognitive devices (Lakoff & Johnson, 2003) often used by designers to encode systems of deep relations into a concise verbal description (Casakin, 2006) that enables the development of a conceptual understanding of the design activity (Hey et al., 2008). Surprisingly, some of the most celebrated JRGs (such as Ryōan-ji, Kyoto; recognized by UNESCO as a world heritage site in 1994) were designed using metaphor-based practices more than half a millennium ago. Given their frugal nature, which focuses on spatial design using a well-defined collection of elements, JRGs serve as a solid ground for studying this practice in a systematic manner.

In traditional JRGs, using metaphoric descriptions such as "Buddhist triad" (Fig. 4-1; Mansfield & Richie, 2009) to describe a rock composition is a common practice. These short

[53] Published in "Artificial Intelligence for Engineering Design, Analysis and Manufacturing"; see (Kahlon & Fujii, 2020a).

titles enabled JRG designers to establish a unique design language, cleverly tying spatial relations with linguistics expressions, offered to the designer as intuitive design catalysts. Using these expressions as the basis for designing a rock composition demands designers to: (1) interpret the metaphor in terms of spatial relations, (2) select the rocks for the composition, and (3) position them in the garden space.

Figure 4-1 "Buddhist Triad" compositions; (a): Buddhist Triad rock configuration at Daitoku-ji, Kyoto (Mansfield & Richie, 2009)[54]; (b): Buddhist Triad sculpture[55], ~1100 AD (Source: Kyoto National Museum).

JRG compositions are created using "ready-made" elements, i.e. the rocks must be used as they are found in nature (Takei & Keane, 2001). Consequently, the resulting design largely depends on the inherent properties of each rock, and its relations to those of the other rocks in the composition. We may say that each rock has a potential to enable certain visual interpretations when combined with other rocks in the garden space (for example, a tall rock can make a neighboring rock appear shorter). To describe this potential, emerging from the possible visual interaction between different rocks, we propose the term "complementary visual potential", which can be seen as the ability to enable another rock to fulfill its metaphoric role in the composition.[56] Utilizing the concept of complementary visual potential, a framework for metaphor-based design is proposed and implemented, in attempt to auto-generate alternative designs for an existing rock composition in a famous JRG. The alternative designs are presented, and conclusions are drawn regarding the ability of the framework to support a metaphor-based conceptual design process. Important definitions and abbreviations are provided in Tables 1, 2 and 3.

4.1.1 Aims and Scope

This chapter aims to clarify how we can systematically relate simple structures with metaphoric interpretations, by studying this practice in the context of JRGD. As an initial effort to establish a clear foundation for formalizing this practice, this study focuses solely on simple compositions consisting of three elements, and on the translation of possible metaphoric relations into spatial configurations in such settings.

[54] also see Fig. 4-9.
[55] Commonly referred to as an "Amida Raigo Triad".
[56] Further discussed in the next section, under 4.2.4.

In this, we exclude other JRG elements, i.e. pebbles, moss etc., from consideration. While such elements may indeed play a significant role in our experience of JRGs, we can regard them as a higher-level aspect of the design, which may be attended to in further studies. This is consistent with the traditional guidelines for JRGD mentioned in Takei & Keane (2001) and by Van-Tonder & Lyons (2005). According to these, the positioning of rocks guides the design, and serves as a basis for the selection and placement of other design elements.

4.1.2 Objectives

Two main objectives were set: (1) identify the main principles which underlie the metaphor-based design process well-established in traditional JRG design and organize them into a coherent design framework, and (2) test the framework by implementing it in a 3D environment via generating alternative designs for an existing three-rock composition.

4.1.3 Significance

This study contributes to the understanding of interpretation in design, as an interaction between the spatial properties of the design elements and their metaphoric descriptions. We present the potential target groups which may benefit from this study, in a (suggested) rising order of relevance: (1) theorists of design and design cognition who are interested in the mutual dependency between design elements in visual design; (2) knowledge engineers, as a basis for a knowledge representation framework which formalizes this dependency; (3) designers of any discipline incorporating a visual dimension who would like to better understand the practice of utilizing metaphors in design; (4) software developers of intelligent CAD systems and/or design agents targeted at supporting the translation of metaphoric relations into spatial configurations.

We also provide possible utilizations of the framework. For theorists of design and design cognition the framework can be used as the basis for conducting empirical studies of the relation between metaphoric interpretation and spatial configuration, and for identifying common practices in assignment of roles which project relations and expectations onto the design elements. Other designers engaged in the visual dimension may benefit from the framework through examining their designs from the perspective of element roles and their related expectations which are mutually projected. Finally, software developers of intelligent CAD systems could integrate the framework into CAD environments with logical inference systems for enabling spatial reasoning based on logical predicates.

4.2 Key Concepts

Here we provide the necessary background for understanding the proposed framework, and define key terms and concepts. These are summarized at the end of this section, in Table 1.

4.2.1 Metaphoric Relationships Between Rocks in JRGs

As evident in the classical manuals for JRG design, the "Sakuteiki" and the "Illustrations"[57], metaphors are extensively used as a basis for the design of rock compositions. This is employed in the design process by assigning names to preferred configurations (see Fig. 4-1) or even short titles containing a concise narrative such as "a tiger carrying its cubs across a river" (Yamada, 2009). These metaphors are not merely verbal descriptions imposed on the design as an afterthought, but rather sophisticated design tools which tie form, position and meaning (Nakagawara, 2004; Slawson & ZoÌen, 1991). In this study we focus on metaphors expressed by concise verbal descriptions which assign roles for each design element, mainly by personification. In the context of JRGs, such metaphors assign visual roles to rock elements, and thus imply that certain spatial relations are expected to be maintained with neighboring rocks, as discussed below.

4.2.2 Main and Secondary Elements

Our approach to formalizing the design process of rock compositions depends on one of the fundamental instructions given in the "Sakuteiki"[58] regarding how one should go about positioning the rocks in the garden: "Choose a particularly splendid stone and set it as the Main stone…following the request of the first stone, set others accordingly" (Takei & Keane, 2001, p.181).[59] We interpret this instruction as guiding the designer to select a first rock (hereafter referred to as a main rock), examine its prominent features and add rocks to the composition (referred to as secondary rocks) in relation to the features observed. This distinction between main and secondary rocks can be generalized to a broader context as a distinction between main and secondary design elements; main elements are selected by the designer (independently of other elements) as an anchor for the composition, while secondary elements are added in relation to the main ones, in attempt to fulfill certain metaphoric relations.

4.2.3 Roles, Behaviors, and Spatial Relations

The metaphoric relations mentioned above are the product of the roles implied by the metaphor, which is chosen by the designer as a basis for creating the configuration. For example, if we wish to design a composition based on the metaphor "mother protecting children", we may map the role "mother" onto the main design element, and the role "children" onto the secondary ones. The relationship the designer associates with these roles will correspond with behaviors that the main element demands secondary elements to fulfill, hereafter referred to as expected behaviors (Gero, 1990).

[57] Translated in (Takei & Keane, 2001), (Slawson & ZoÌen, 1991) accordingly; note that both were written by unknown authors.
[58] Generally considered as the top classical manual for JRGD.
[59] Given as the second instruction in the "Setting Stones" section, following the instruction of carrying rocks to the site etc.

When creating a composition, we define our design goal as to enable the main element to fulfill its metaphoric role in the composition, which occurs when the secondary elements fulfill their expected behaviors. This requires determining which elements are proper candidates to fulfill the expected behaviors imposed on them by the main element, by evaluating their complementary visual potential, as explained in 4.2.4.

In the context of JRGs, the main rock may be assigned with different roles, each imposing certain expected behaviors onto its secondary rocks in the composition. Typical linguistic (semantic) metaphors underlying the spatial relationship of rock arrangements are "Buddhist triad", "teacher-student" and "mother-children". While at first glance these may seem rather different, their similarity is readily revealed when considered through the lens of East-Asian thought: the 5 Relationships of Confucianism set basic guidelines for human relations, based on the concept of superior-inferior. This is complemented by the yin-yang theory, which emphasizes the fundamental dependencies existing between seemingly opposing or contrasting elements in the world. For example, a teacher is referred to as superior only in relation to a group of students, who are his/her inferiors.[60] Analogously, rock arrangements which correspond with the above linguistic expressions consist of one superior figure (main; imposing expected behaviors) and at least one inferior figure (secondary), and are therefore often expressed visually and interpreted conceptually as interchangeable, if not identical.

4.2.4 Concept of Complementary Visual Potential

The concept of complimentary visual potential finds its roots in the concept of affordance (Gibson, 1979) and its view as an "ability", as proposed by Kannengiesser & Gero (2012) or an "action possibility" (McGrenere & Ho, 2000). Accordingly, we precede its definition with a brief discussion of affordances. An affordance can be seen as a visual cue for possible interactions with an object (Soegaard, 2002), owing either to its inherent or perceived properties. While there are different approaches regarding the nature of affordances, it is generally agreed that the existence of an affordance depends on the spatial relations between an agent and an object. For instance, if an object is to afford "grasping", its physical dimensions and shape need to match the hand of the grasping agent.

In the domain of visual design, each element in a composition has various properties which may enable different visual impressions for the viewer, when combined with other elements in the composition. For example, one object may enable another to appear very large, if the former is significantly smaller than the latter. Therefore, from the standpoint of viewing affordance as an ability depending on spatial relations, we may say that elements in a composition also "afford" certain behaviors to each other. Maier & Fadel (2009) have proposed

[60] As nicely put by Alan Watts: "I can't play the teacher unless you play the student" (Watts, 2017).

the notion of "artifact-artifact affordance" which is relevant for our discussion; however, since our study focuses on the visual aspect of interaction between design elements, we use the term "complimentary visual potential" to describe this ability, in order to avoid confusion with the concept of affordance, which stresses the aspect of function.

Kannengiesser & Gero (2012) proposed a model which conceptualizes the relation between affordances and behaviors via a construct with input parameters matching the affordance. This model is used here to represent the concept of complementary visual potential, which can be seen as a coupled structure tying two objects and their potential behaviors (Fig. 4-2). We define complementary visual potential as the ability of an object to enable another object to fulfill an expected behavior in the composition.

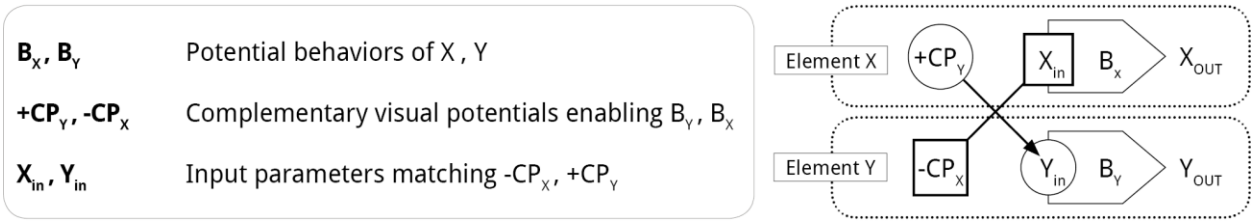

Figure 4-2 Complimentary visual potential; represented on the basis of Kannengiesser & Gero (2012).

In Figure 4-3 we provide a simple example using two objects, to explain how complementary visual potentials contribute to formalizing the mutual dependency that characterizes the relation between design elements. Behaviors here can be thought of as adjectives or verbs corresponding with sets of spatial relations (for example: "wide" can correspond with certain measurements). The two objects *x,y* are of different sizes; if we wished *y* to fulfill the behavior "tall", *y* would need to maintain certain spatial relations with the other elements in the composition, which correspond with this behavior. Therefore, adding an object which fulfills these spatial relations, would enable *y* to fulfill the desired behavior. Being shorter, *x* can complement the behavior "tall" for *y*, and thus owns the required complementary visual potential for our goal. Notice that this is a two-way relationship, and *y* also owns a complementary visual potential in relation to *x*, i.e. to enable it to fulfill an opposite behavior which may be called "short". Although this example focuses on a single spatial relation, complementary visual potentials may also result from multiple spatial relations. With respect to JRG design, complementary visual potentials can serve as criteria for filtering and selecting candidate secondary rocks out of a large collection, in accordance with the design goal.

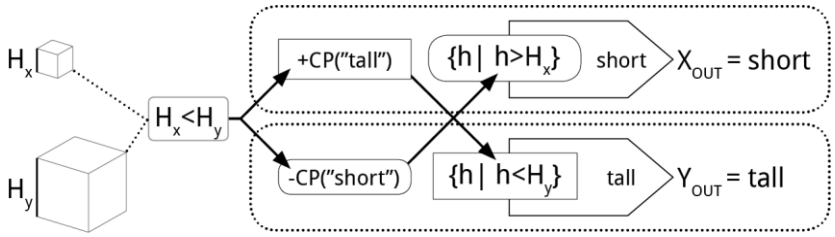

Figure 4-3 Example of complimentary visual potentials emerging from a height difference.[61]

Table 1 Key terms used in section 4.2.

Term	Definition	Example
Metaphor	A concise linguistic expression referring to the design elements & assigning them with roles, often via personification	(These rocks are) "teacher & student"
Design element	A physical part of the designed artifact (or its representation) which is defined as an undividable unit by the designer	Rock, moss patch etc.
Main element	The first element placed in the composition, selected by the designer independently of other elements	Fig. 4-1, middle rock
Secondary element	Any element selected and added to the composition in relation to the main element	Fig. 4-1, left rock
Complimentary visual potential	The ability of an element to enable another element to fulfill an expected visual behavior	In Fig. 4-1, the right rock renders the middle as "tall"

4.3 The Proposed Framework

Every spatial configuration has two distinct (yet related) aspects: its physical forms (i.e. the design elements) and its verbal description (i.e. the linguistic phrase from which we can derive the metaphoric relations to serve as a basis for the design). The following framework aims to create a relation between the Spatial Relations World (SRW) emerging from the forms and their spatial configuration, and the Metaphoric Relations World (MRW) emerging from the description. This is done by defining two corresponding spaces: Behavioral Potential Space (BPS) and Behavioral Expectation Space (BES). This construct was inspired by the "Dual Deep-Structure" proposed by Fujii & Aoki (2003) for establishing a relation between shapes and their linguistic descriptions. Yet, here two mediating spaces are added – Interpretation Space (IS) and Complementary Visual Potential Space (CVPS). Abbreviations and definitions are summarized at the end of this section in Table 2; the complete framework is shown below (Fig. 4-4).

[61] As previously mentioned, represented on the basis of Kannengiesser & Gero (2012).

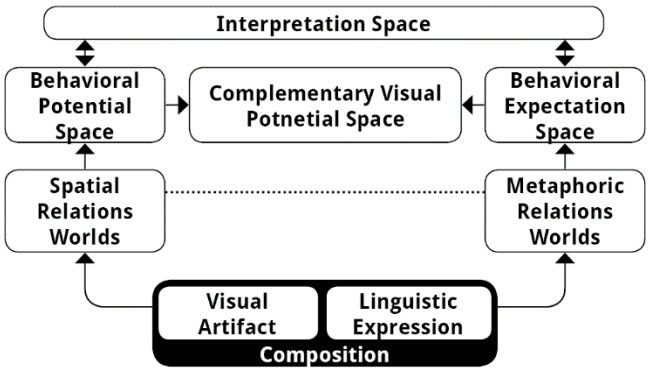

Figure 4-4 The proposed framework for relating spatial configuration and metaphoric descriptions.

4.3.1 Spatial Relations World (SRW), Metaphoric Relations World (MRW)

SRW is concerned with low-level spatial relations that may be identified in the artifact through measurement and comparison, as well as with higher level relations that may be derived from them via deduction. Given two objects *x* and *y*, these relations are represented as simple propositions in the form *relation(x,y)*. For example, the fact that *x* is taller than *y* is represented in SRW as *taller(x,y)*. MRW on the other hand, is concerned with the roles of the design elements which are implied by the linguistic expression. These are represented in the form *roles(main_role, secondary_role)*. For example, given the expression "master teaches student", a possible formalization of the roles may be *roles(master, student)*.

Referring back to Fig. 4-1, possible expressions of the composition in SRW are *shorter(secondary,main), wider(main,secondary)*. Possible expressions of the composition in MRW are *role(teacher,students), role(father,children)*. Given a rock composition, by examining it through the lens of SRW we can identify spatial relations between the rocks, which result from their configuration in space, as well as from their inherent properties. By examining it through the lens of MRW, we can identify certain roles implied by the metaphoric relations in the verbal description. From these emerge BPS and BES, accordingly.

4.3.2 Behavioral Expectation Space (BES), Behavioral Potential Space (BPS)

Behaviors are entities represented by verbs in the English language. Each behavior receives its spatial meaning from the correspondences specified in the IS (see 4.3.3). A behavior is said to be well-defined if and only if there exists a spatial relation in IS which corresponds with it. An object *y* is said to fulfill a behavior *b* in relation to an object *x*, if and only if *b* is well defined and *y* fulfills the spatial relation that correspond with it in IS, in relation to *x*. The fact that *y* fulfills the behavior *b* in relation to *x* is expressed in the form *behavior(x,y)*.

BES emerges from MRW and consists of sets of behaviors which one object may expect another to fulfill, called expectation sets. Each behavior in the expectation set is referred to

as an expected behavior. Let B represent a BES and let B^* represent the finite set of all well-defined behaviors. Then $B=\{E_1,..,E_t\}$, where each E_j is an expectation set in the form $E_j=\{b_1,...,b_m: b_i \in B^*\}$. The set *{bow(x,y), listen(x,y)}* may serve as an example for an expectation set containing two expected behaviors of an element x from an element y.

BPS emerges from SRW and consists of sets of behaviors that can be fulfilled in practice by an object x. Let B' represent a BPS; let $S(\subseteq B^*)$ represent the set of all behaviors that x can fulfill in relation to y. B' is then given by the power set of S, so that $B'=P(S)$. Each item in B' consists of a combination of potential behaviors, i.e. set of behaviors which may be actually fulfilled, thus referred to as a potential set. Since B' contains all of the possible combinations of behaviors that x may fulfill in relation to y, it provides us useful information regarding whether x can meet the behaviors in a given expectation set of y. This will determine x's ability to enable y to fulfill its role in the composition.

4.3.3 Interpretation Space (IS), Complementary Visual Potential Space (CVPS)

IS enables us to give spatial expression to our behaviors by assigning each with a corresponding spatial relation. Let $I=\{i_1,....,i_n\}$ represent an IS; Every $i_j \in I$ denotes an interpretation for a single behavior so that $I=(b,R)$, where b is a behavior of the form *behavior(x,y)* and R is a set of spatial relations that may occur between the two elements, each in the form *relation(x,y)*; in other words, each i_j represents a single correspondence between a behavior and its spatial expression. For example, the behavior of "bowing" may correspond with being physically shorter, and can therefore be expressed as $i=(bow(x,y),\{shorter(x,y)\})$. This ties the behavior of an object with the spatial relations it fulfills with another in the composition.

CVPS results from the intersection of BES and BPS, and enables an evaluation of the ability of one object to fulfill the expectations of another. Let C represent a CVPS; C is given by $C=B \cap B'$. Since B is populated with expectation sets of x, and B' is populated with potential sets of y which may fulfill them, C consists only of the expectation sets which can be fulfilled in practice by y in relation to x. When an expectation set of x is fulfilled by y, we say that x fulfills its role in the composition and that y owns the complementary visual potential for that role. Thus, when $C \neq \emptyset$ we can say that there exists at least one potential set of y which fulfills an expectation set of x, and y can enable x to fulfill its role in the composition.

Table 2 Abbreviations used in section 4.3.

SRW, MRW	Spatial Relations World, Metaphoric Relations World
BES, BPS	Behavioral Expectation Space, Behavioral Potential Space
IS, CVPS	Interpretation Space, Complimentary Visual Potential Space

4.4 Results

4.4.1 Experimental Implementation

The proposed framework was implemented by constructing three sub-systems assigned with the following tasks: interpretation, selection and positioning (Fig. 4-5). This is in accordance with the three main operations in JRGD: interpreting a metaphor in terms of spatial relations, selecting rocks suitable for the current design task and positioning them to convey the metaphoric relationship. The systems were integrated with a 3D CAD environment (Rhinoceros 3D) and used to generate spatial configurations of simple rock compositions based on metaphoric relations, as described hereafter. Important definitions are given at the end of this section in Table 3.

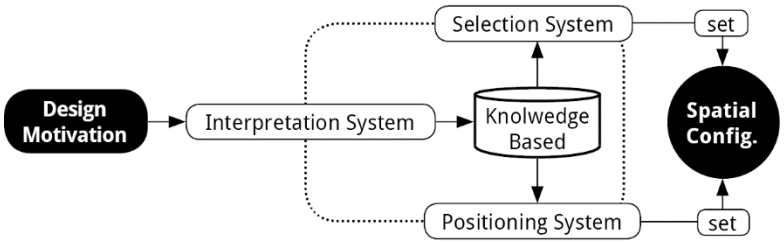

Figure 4-5 Spatial configuration design as a product of three integrated sub-systems.

4.4.2 System Behavior

During initialization, the system utilizes three elements as catalysts for the design of a rock composition: a main rock, a metaphoric relation and a set of observed properties (see Table 3). These serve as decision variables, and are collectively referred to as the design motivation.

In order to generate a rock composition using the system, the user is required to set the design motivation by selecting a main rock and assigning values to its observed properties. The system will then: (1) pass the design motivation to the interpretation system to convert it into expected behaviors[62]; (2) pass these into the selection system for choosing two suitable candidates for the secondary rocks; (3) pass the chosen candidates to the positioning system to set them in place, also in accordance with the demanded spatial relations. The complete process is summarized in Figure 4-6.

[62] This can be seen as a "pre-processing" phase (Kannengiesser & Gero, 2012).

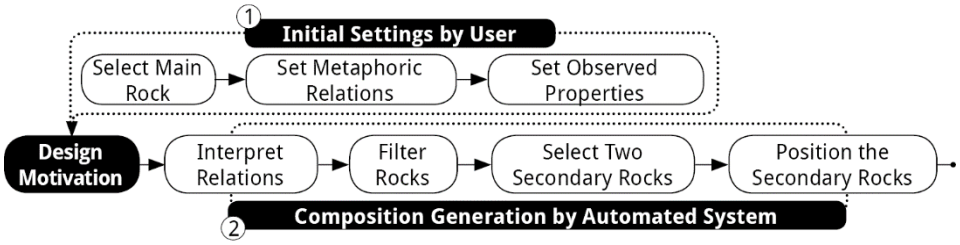

Figure 4-6 Producing a metaphor-based rock configuration using the implemented system.

4.4.3 Sub-systems and their Roles

As mentioned in 4.4.1, the complete spatial configuration generation system consists of three sub-systems. The general behavior and tasks handled by each are described below.

The interpretation system's main task is to convert the metaphoric relationship into expected behaviors. These behaviors will enable the selection system to evaluate the complementary visual potentials, and thus serve as the criteria for filtering the secondary rocks, and selecting those that can enable the main rock to fulfill its role.

The selection system receives the expected behaviors from the interpretation system and attempts to select appropriate secondary rocks, i.e. ones which will enable the main rock to fulfill its role in the composition by: (1) filtering the rock collection from secondary rocks which cannot fulfill the expected behaviors, and (2) randomly selecting two rocks from the filtered rock collection and passing them to the positioning system.

Figure 4-7 outlines the general structure of the system's core; this consist of the interpretation and selection systems, as well as the resources involved in the process of interpreting the design motivation and selecting adequate secondary rocks, which are then passed to the positioning system.

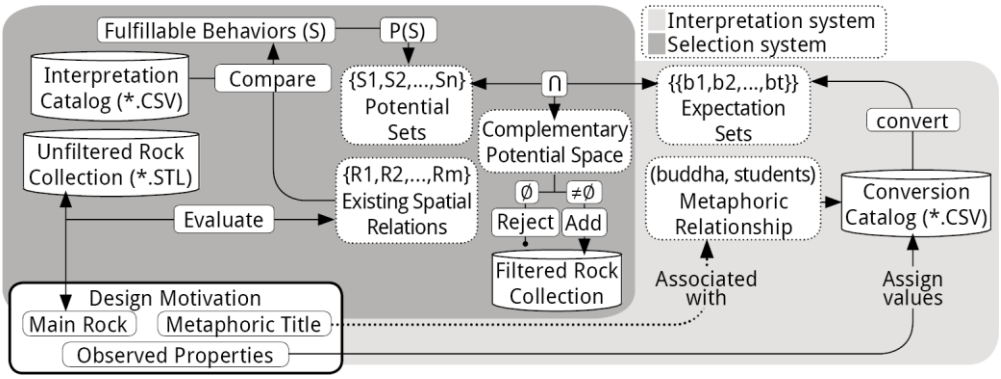

Figure 4-7 Outline of the system's core - the interpretation and selection systems.

The positioning system aims to position the selected secondary rocks around the main rock, in accordance with the metaphoric relationship and its corresponding expected behaviors. Setting the position for the secondary rocks involves three parameters: proximity, relative position (in front, behind etc.) and orientation, all in relation to the main rock. The system reads the spatial demands corresponding with the expected behaviors and positions the secondary rocks in three phases: (1) initialization: the secondary rocks are arbitrarily placed around the main rock in a pre-defined boundary, serving as the environment for the generation of the composition; (2) gathering: the secondary rocks attempt to approach the main rock to fulfill the demanded spatial relations concerning with proximity; (3) orienting: the secondary rocks will circulate around the main rock and around their pivot axes, in order to fulfill the demanded spatial relations. Figure 4-8 shows a simple positioning process of two secondary rocks around a main rock.

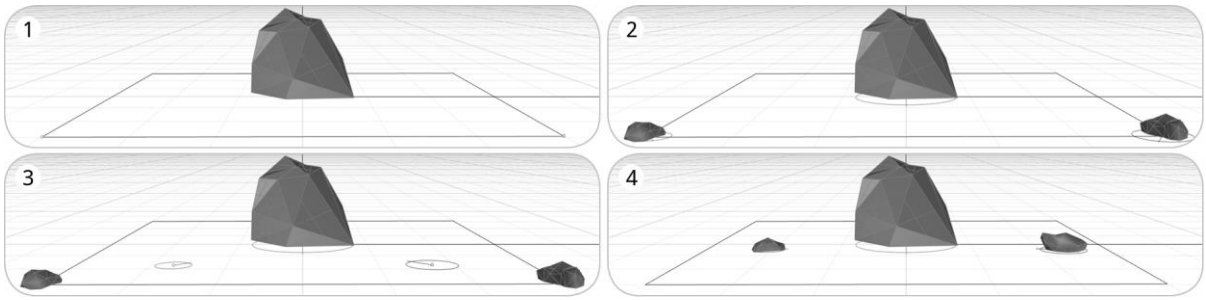

Figure 4-8 Auto-positioning the secondary rocks around the main rock.

4.4.4 Generating Alternative Designs for an Existing Rock Composition

The implemented system was tested by attempting to generate alternative designs for an existing rock composition, found in the garden of Ryōan-ji (Figs. 4-9, 4-10). The original main rock was maintained (Fig. 4-9, middle rock) while the secondary rocks were replaced and

repositioned, by reinterpreting the metaphoric relation in different manners, as explained hereafter.

The main rock in the composition was modeled in 3D after the original, according to photographic documentation taken from multiple angles. The rock collection used for the generation consisted of 48 small rocks, digitally scanned using a desktop 3D scanner, each used in 4 different scales, resulting in a total of (48x4=)196 rocks.

Figure 4-9 A Buddhist Triad rock composition at the famous garden of Ryōan-ji, Kyoto.

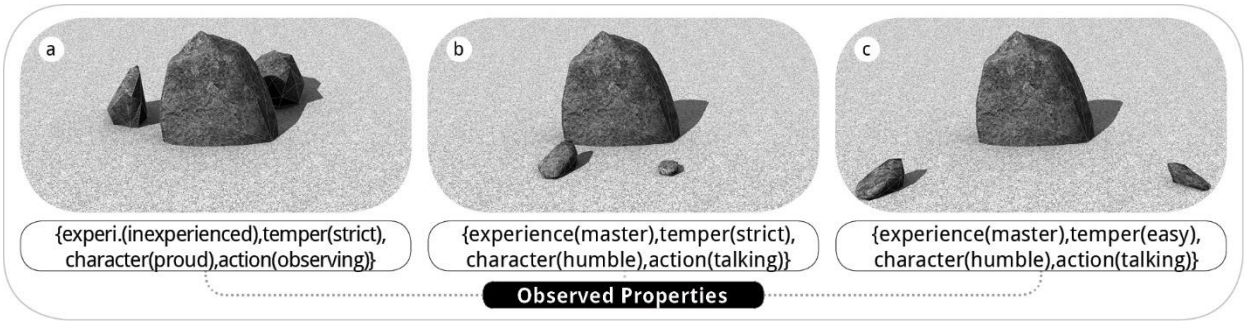

Figure 4-10 Generation of alternatives to the configuration in Fig. 4-9.

According to the metaphoric relation in the original composition, the main rock was assigned with the role of "teacher" and the secondary rocks with the role of "students". Alternative designs for the original composition were produced by assigning different values to the observed properties of the teacher rock, which determined the selection and positioning of the student rocks. Each set of values represents a different interpretation of the metaphoric relation, as explained below. Figure 4-10 shows the different sets of the observed properties assigned each time to the teacher rock, and the resulting rock configurations.

Table 3 Entities of the implemented system and their formal representation.

Entity	Definition	Representation	Example
Element	A single rock stored as mesh geometry with a unique id	e(id)	*e(32)*
Spatial Relations Set	Finite set of spatial relations occurring between two design elements x and y	srs(x,y)	*{shorter(x,y),wider(x,y)}*
Behavior	A pairing of a single verb in the English language with a Spatial Relations Set	behavior(name,srs)	*behavior("bow",srs(x,y)), srs(x,y)={shorter(x,y),in_front(x,y)}*
Role	A pairing of an element with a single Noun appearing in the linguistic expression describing the compos.; for example, "Mother with children" contains the possible roles "mother" and "children"	role(e,role_name)	*r(e(65),"buddha")*
Metaphoric Relation	An ordered pair of roles correspond. with a set of behaviors the secondary elements are expected to fulfil	mr(r, r') Where r,r' are roles	*mr(role(e(20),"buddha"), role(e(51),"student"))*
Observed Property	An attribute assigned to the main element by the user via selection from several possible values	op(prop_name,value)	*op("character","humble")*
Design Motivation	A set of decision variables which includes the chosen main element, a metaphoric relation and a set of observed properties	{e(id),mr(r,r'),O} where O is a set of observed properties	*{e(26),mr(…), {op(character,humble),…}}*

4.4.5 Interpreting the Results

The generated compositions aim to demonstrate the possibility of tying a metaphoric relation with a spatial expression, using our framework. In order to clarify how the metaphoric relation is expressed spatially in the compositions, we firstly explain the relationship between the observed properties assigned to the main rock and the resulting configuration. As an example, we focus on the property of "experience". In all three compositions the main rock is assigned with the role of "teacher", while the secondary rocks are assigned with the role of "students". As a teacher, the main rock may be further described as either a "master" or "inexperienced". Since a master is more likely to expect deep respect from his students (compared with an inexperienced teacher), asserting the teacher as having the observed property op(experience,master), will demand the secondary rocks to fulfill the expected behavior of "bowing", so that the students can express their respect to the teacher. The

behavior of "bowing" is spatially interpreted as being relatively short[63], and as we see in Figure 4-10(b), the student rocks were selected so as to fulfill this criterion. This expected behavior can be briefly stated as behavior(bow,{shorter(x,y)}), although additional spatial demands may be further integrated according to the user's considerations. In contrast, the assertion that the teacher is "inexperienced, i.e. having the property of op(experience,inexperienced), results in a lack of expectation for "deep respect". This is expressed in the selection of vertically oriented rocks which "stand" (i.e. do not bow), as seen in Figure 4-10(a). For clarification purposes, an example for the above correspondence between an observed property and its spatial expression (determined by an expected behavior) is diagrammed below in Figure 4-11.

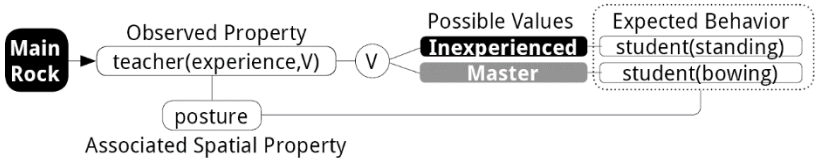

Figure 4-11 From an observed property to an expected behavior.

4.5 Discussion

4.5.1 Evaluation

The implementation of the proposed framework focuses on the fundamental entities and considerations involved in translating a metaphoric relation into a simple spatial configuration, and is based on our understanding of this practice in JRGs. This enables us to examine the framework's ability to serve as a basis for embodying a given metaphoric relation within a spatial configuration via: (1) elaborating the relation as a set of related qualities which may be assigned to the main element, i.e. our observed properties; (2) assigning each observed property with a corresponding expected behavior that the main element may demand the secondary ones to fulfill; (3) tying these behaviors to spatial relations that the secondary elements are consequently required to fulfill.

In this manner, the complete construct of observed properties, expected behaviors and spatial relations can be seen as an elaboration of the metaphoric expression, which may be used as design knowledge for constructing, as well as interpreting, spatial configurations.

The entities in our implementation are representations of our translation for JRG design principles; the observed properties entity is an exception to this rule, and therefore requires further elucidation. As explained in section 2, the basic instruction of JRG design guides the

[63] This is a common interpretation in JRG; see Figure 4-1.

designer to select a rock, "listen to its request" and act in accordance with it. From a phenomenological perspective, we may view this stage as implicitly guiding designers to form their initial intentional stance for creating the composition, by extracting certain properties suggested by the rock. This can be seen as an interaction between the designer and the main rock, in the form of a mental activity. Fujii et al. (2013) have proposed the FNS model for describing the formation of the intentional stance of the designer as a result of interaction with the external world. This model uses the term "current noema" to refer to the designer's experience of the current situation. The current noema is said to form through a process of analysis, which occurs through three sub-processes of observation, evaluation and narration. The last phase of forming the intentional stance thus results with a narrative which includes the understanding of the current situation. To represent this understanding acquired from observing the rock, we defined the entity of "observed properties", which are properties that may be assigned with different values by the designer. These properties are neither quantitative nor objective evaluations of the main element, but rather conceptual descriptions which the designer associates with it after a careful observation. The observed properties thus serve as an instrument to represent the current noema (resulting from observing the main element) as a set of properties which can be given a spatial expression.

4.5.2 Generalizability of the Framework

While the framework was introduced through the lens of JRGD, it is fundamentally independent of a specific design discipline, and may be utilized in other areas of design which involve spatial configuration, for tying metaphoric expressions with spatial relations. The framework is targeted for use at the conceptual design stage. In order to utilize it in a computational system, regardless of the specific design context, it is required to conduct a preliminary three-phase process of: (1) identification and formalization of the domain's design elements, (2) specification of the common spatial relations that may occur between these, and (3) translation of these into behaviors coupled with spatial relations. These may serve as an initial knowledge base for implementing intelligent agents in CAD systems, which can support metaphor-based design processes. In Figure 4-12 we present a simple example for creating several spatial configurations based on a single element, a metaphoric relation and a related expected behavior, imposed on the secondary elements as a result. For example, in Figure 4-12(b) we have translated the observed property of being perceived as tall to refer to the element as the "peak of the district", which results in an expectation of the surrounding object to fulfill certain behaviors (being shorter than the main element, having a vertical appearance in order to resemble typical tall buildings etc.).

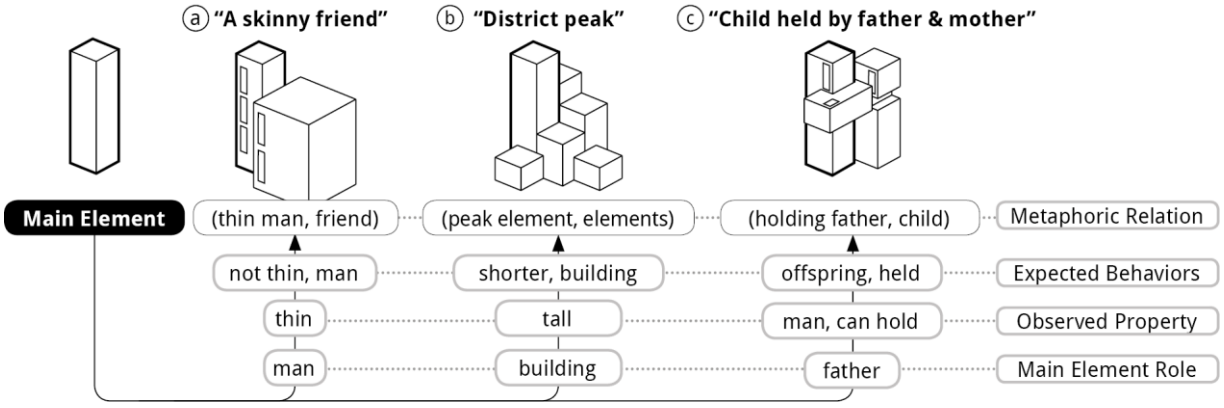

Figure 4-12 A single element in various spatial configurations, expressing different metaphoric relations.

4.5.3 Future Work

The framework presented in this chapter systematically relates the metaphoric interpretation of structures with their spatial configuration. In order to utilize the framework, it is necessary to couple spatial relations with behaviors of elements[64]. These are currently specified in IS[65] via manual input of such pairings. While feasible in simple conceptual design tasks, demanding users to specify each interpretation in IS a priori may prove inadequate for projects of greater complexity. This is due to the time-costly nature of this process, as well as to the improbability of sufficiently covering the (potentially) vast spaces of possible behaviors and interpretations. This issue may be approached by enabling users to share their IS, potentially leading to a development of public interpretation repositories which are context-based.

Yet, before proceeding in this direction, a preparatory step should be taken to adapt the framework to a standardized knowledge representation system. This will serve as a strong basis for both phrasing and sharing interpretations among designers, as well as facilitating the use of logical inference engines for reasoning purposes. The chosen representation system would preferably: (1) enable to phrase metaphoric interpretations formally in an intuitive manner, and (2) support comparison between various interpretations created by different users. A possible candidate is the Ontological Logs ("Ologs") framework by (Spivak & Kent, 2012), yet this requires further inquiry.

Additionally, is it important for future versions of the framework to address non-hierarchical relations between elements, which often occur in design. This may be done by reformulating

[64] Refer back to 4.5.2.
[65] Refer back to 4.3.3.

it as to enable each element to have expectations from others, regardless of its position in a hierarchical structure.

4.6 Conclusion

This chapter has examined the metaphor-based design methodology employed in JRGs, as a vehicle for gaining insight into practices of interpretation of structure in design. A framework for relating structures with interpretations was proposed, implemented, and tested, in this context. The proposed framework enabled to utilize metaphoric interpretation as a basis for forming structures, by coupling spatial relations with linguistic expressions.

From the perspectives of design-theory, the proposed framework suggests key-concepts which are essential for systematically describing interpretation processes, thus serving as a strong foundation for striving towards its modeling and formalization. Additionally, from the perspective of computational design, we view this study as a first step towards integrating metaphor-based interpretation capabilities into CAD systems, which can potentially extend their capacity to support conceptual design processes.

Considering the potential of enhancing CAD systems' ability to engage in metaphoric interpretation, what steps can we take in this direction? A precondition for making further progress is the ability to explicitly represent and store interpretations within a knowledge base, for repeated use. In the current framework, metaphoric interpretations are only represented implicitly, as a combination of several distinct entities (properties, rules etc.). This is in contrast to real design practices, where designers often "store" a concise metaphoric expression, which binds such properties and rules in a memorable manner. The challenge of explicitly representing metaphoric interpretations within a computational system, in an intelligible manner, is thus approached in the next chapter.

Chapter 5 A Framework for Representation of RIs in a CAD System: a Case Study of JRGD[66]

This chapter asks the following question: how can we formally represent RIs in conceptual design? Towards answering this question, we propose a framework for knowledge representation within a computational system, in the context of JRGD, as a case study. The framework is implemented by integrating a CAD system with a logical inference engine. We test the framework by attempting to automatically match structures with possible metaphoric interpretations, stored in a knowledge base. A direct consequence of this study is the extension of our ability to inform CAD systems regarding subjective meanings of structures for the user. This marks an important step towards reducing the conceptual gap between the user and the CAD system, with respect to their ability to interpret structures.

5.1 Introduction

Computer-Aided Design (CAD) systems enable designers to create digital representations of their designs by storing, manipulating and visualizing information regarding the designed artifact's configuration (Fujii & Aoki, 2003). Utilizing object-oriented approaches, CAD systems continuously strive to minimize the gap between the designer's conceptual understanding of the artifact being designed, and its digital representation (Kalay, 2004). As a result, advanced CAD systems are highly informed with respect to the representation's denotative meaning in the designer's conceptual world. This is evident in Building Information Modeling systems for architecture, where a set of elements is often associated with a higher-level entity; for example, a set of window parts is encapsulated in a single object of a window, informing the system of this high-level denotation.

Contrary to this, most systems are less informed regarding the representation's connotative meaning in the designer's mind. This chapter proposes an implementable framework for concept representation in CAD environments, to enable designers inform the system regarding possible connotative meanings of spatial configurations, in a given context. This is conducted by representing and storing spatial configurations as high-level descriptions, enabling designers to encapsulate desirable design typologies in concise verbal expressions. The proposed framework was implemented and tested in the context of JRGD, by storing

[66] Published in "Computer Aided Design and Applications" ; see (Kahlon & Fujii, 2020b).

popular rock configuration typologies as short verbal descriptions, and retrieving them from memory.

5.1.1 Background

Tying desired sets of spatial relations under a single verbal description is an old-time design practice, evident as early as in the classical Greek orders of architecture (Fig. 5-1), where certain proportions and parts are explicitly named as a single entity (i.e. Doric etc.). These names form a conceptual framework for the design of artifacts, by serving as high-level abstractions of multiple spatial relations. Such abstractions denote a range of desired design solutions, while connoting with additional possible meanings that may be attributed to the artifact by the designer. In the above example, the description "Doric" denotes a certain set of column parts and their relative proportions, while connoting the design with the concepts of masculinity and dignity often attributed to such columns (Onians, 1988).

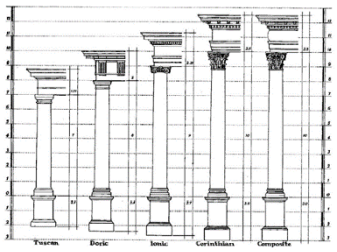

Figure 5-1 The Greek orders; an early form of formalizing spatial relations; (source: Chitham, 2005).

Facilitating the above practice in current CAD systems will not only enable designers to construct digital conceptual frameworks, but will inform the system with respect to high-level semantic attributes which the designer associates with a given spatial configuration. How may we formalize this practice, to enable its support by current CAD systems? Various disciplines such as structural and mechanical design have long recognized the potential and advantages of informing systems of high-level abstractions, referred to as "features" of the design (Catania, 2007; Salomons, van Houten, & Kals, 1993; Shah, 1991). These refer mainly to structural (Zamanian, Fenves, Thewalt, & Finger, 1991) and functional (Feng, Huang, Kusiak, & Li, 1996) properties of a given configuration of the designed artifact. We propose to approach the conceptual descriptions used by designers as a type of visual feature of the spatial configuration.

This chapter examines the practice of assigning spatial configurations with high-level conceptual descriptions it in the context of JRGD; this has served as suitable grounds for an initial investigation of this practice, owing to two main considerations: (1) its frugal nature

consisting of a relatively small number of well-defined elements, and (2) its flexibility with respect to the structure and usage of conceptual descriptions.[67]

As an abstract form of art, JRGD makes extensive use of conceptual descriptions denoting a specific design typology, to the extent of offering a composition catalog for designers, as a reference for selecting and positioning rocks in the garden space (Slawson & Zoìen, 1991). These descriptions are not arbitrary names, but rather connote with high-level meanings that are attributed to the design. In Figure 5-2(c) we present an example of a configuration attributed with the concept "Dry Waterfall". This attribution implies on certain spatial relations (for example: verticality, downward flowing texture etc.), while tying the configuration with connotative meanings external to the designed artifact (the concept of water, natural scenery etc.). By analyzing the relation between the spatial configuration and its description in existing compositions, we may progress towards formalizing this practice of forming conceptual descriptions, to implement it in CAD systems.

Figure 5-2 Examples for common typologies serving as high-level conceptual abstractions in JRGD; (a) "Buddhist Triad" (Tōfukuji temple, Kyoto), (b) "Crane Island" (Tōfukuji temple, Kyoto), and (c) "Dry Waterfall" (Senshūkaku garden, Tokushima; source: japanesegardening.org).

5.1.2 Aim

The aim of this study is to enable users to inform CAD systems regarding possible connotative meanings of spatial configurations, by storing interpretations within formal descriptions.

5.1.3 Significance and Contribution

The main contribution of this study is the proposed computational framework, which enables users to assign meaning to the digital representations of their designs, by adding a layer of high-level semantic descriptions. This framework expands the notion of meaning in CAD systems, enabling designers to embed conceptual information into their digital models. Among the potential implications are: (1) enabling to store and share conceptual frameworks and desirable design typologies among designers, (2) contributing to the development of co-

[67] Compared with the rigid nature of concepts in Greek architecture, for instance, which allows minimal freedom for designers when applying the concepts in their designs.

creative design systems, which are capable of understanding high-level conceptual abstractions, and (3) supporting automatic semantic enrichment processes in CAD systems.

5.2 Method

This study follows the constructive research methodology, which relies on pragmatist views in its attempt to bridge between existing theories and practical problems, via the creation of artifacts (Crnkovic, 2010). Accordingly, in our attempt to address the problem of relating high-level concepts with structures, we follow a similar process, as outlined below.

In order to establish the proposed framework for tying interpretations with structures we have: (1) studied this practice in the context of JRGD design, by conducting a literature review of the traditional manuals (Slawson & Zoìen, 1991; Takei & Keane, 2001) and by documenting rock configurations in classical JRGs; (2) devised a standardized syntax to express common concepts as sets of lower-level entities; (3) digitized a collection of small rocks using a desktop 3D scanner and stored them as mesh geometries, as a preparatory step for the implementation; (4) implemented the framework by integrating the 3D CAD environment with a logical inference system; (5) constructed a set of formal concepts and attempted to automatically match them with spatial configurations using our system. [68]

5.2.1 Scope

This study focuses solely on the spatial configuration aspect of rock compositions in JRGD, excluding other JRGD elements from consideration (such as the moss, gravel etc.); while the other elements greatly contribute to the design and affect its interpretation by users, the traditional manuals of JRGD teach us that the rocks serve as the foundation for the design activity, and are strongly viewed as the backbone of the design (Van Tonder & Lyons, 2005).[69] Accordingly, we have chosen to begin developing the framework by focusing on the rocks, while keeping in mind the need for extending it to include additional elements in the future.

5.3 The Proposed Framework

The proposed framework is used to construct high-level concepts by combining multiple lower-level entities (Fig. 5-3). This framework is inspired by Gero's FBS framework (Gero, 1990) and Gardenfors's Conceptual Spaces framework (Gärdenfors, 2000). We define four main entities: behaviors, relations, meanings and concepts. Each entity is assigned with a

[68] A useful outline of the steps in constructive research, which we draw on, can be found in (Lehtiranta et al., 2015).
[69] Evidently, the classical manual for general Japanese garden design opens with the words "The art of setting stones", reflecting their centrality in this art form (Takei & Keane, 2001).

formal syntactic representation[70], as given in Table 4. The formal syntax enables to harness logical inference systems for matching spatial configurations with high-level descriptions. A valid matching of a concept with a spatial configuration is inferred by logically deriving the existence of the associated lower-level entities in the system.

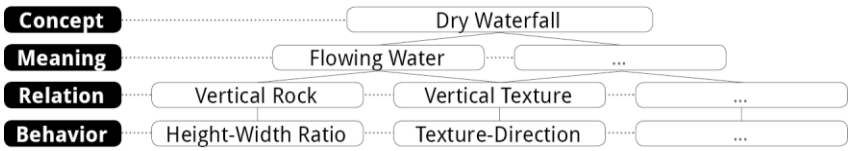

Figure 5-3 A possible partial formalization of the concept "Dry Waterfall" using our framework.[71]

Table 4 Syntax and representation of our basic entities.

Entity	Syntax	Example
Behavior	rock(A,has_behavior(type,value))	*rock(A,has_behavior(width,1))*
Relation	rock(A,has_relation(type,name,B))	*rock(A,has_relation(size,taller_than,B))*
Meaning	rock(A,has_meaning(name,B))	*rock(A,has_meaning(listening,B))*
Concept	concept(concept_name,A,B,C)	*concept(teacher_and_students,A,B,C)*

5.4 Implementation and System Behavior

To implement the framework, we have created a live connection between a 3D environment (Rhinoceros 3d) and an inference system (SWI-Prolog). This implementation enables users to: (1) create concepts based on pre-defined relations and meanings, (2) generate random spatial configurations from a digital rock collection, and (3) automatically match given spatial configurations with existing concepts. The manner of creating concepts and matching them with spatial configurations, as well as the system's structure, are explained below.

5.4.1 Concept Creation

Concepts are represented by rules written in Prolog; a concept is created by combining several lower-level entities, using the syntax presented previously in Table 4. Users can create meanings and concepts by selecting and combining relations from a pre-defined relation pool stored in a knowledge base, via a simple graphical user-interface (GUI), referred to as "concept editor" (Fig. 5-4). In general, all semantic descriptions as well as the newly created concepts, are stored in the knowledge base. Relations are divided into three categories (size, proportion and position) and are either dual or triad (between two or three objects, accordingly). Table 5 presents the different sub-types for each relation type, while Table 6 further presents three different relations that are associated with a single sub-type.

[70] In this, we follow the syntax of the logical programming language Prolog.
[71] See Figure 5-2.

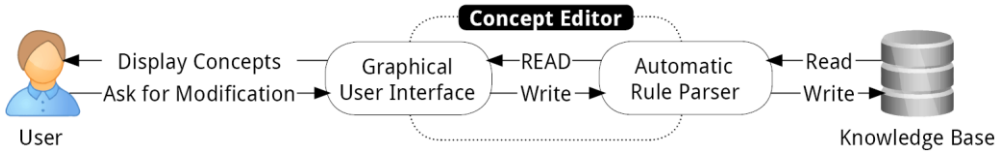

Figure 5-4 Creating and managing a concept knowledge base by utilizing an automatic parser.

Table 5 Object features and their corresponding predefined relations.

Relation Type	Relation Sub-Types		
Size	height	width	depth
Proportion	self-proportions	proportion similarity	proportion difference
Position	side	proximity	overlap

Table 6 Explicit definition of a linguistic description dealing with spatial relations.[72]

Relation Sub-Type	Relation	Condition
Height	"taller"	H1>H2
	"significantly taller"	H1/3>H2
	"tallest"	H1>H2 and H1>H3

5.4.2 Matching Concepts with Spatial Configurations

The implemented system enables to automatically match a given spatial configuration of rocks with a high-level concept, according to the concepts currently defined in the knowledge base. The process of using the system consist of four main steps, as shown below (Fig. 5-5).

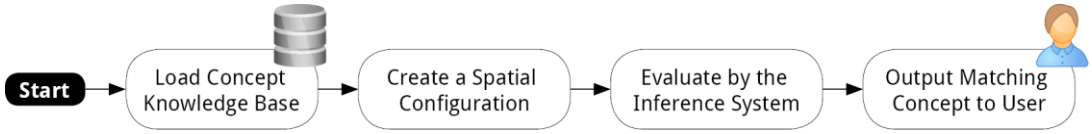

Figure 5-5 Matching concepts with spatial configurations using the system.

In order to enable this matching process, we: (1) read the geometric data from the CAD environment; (2) parse it as facts in Prolog syntax, to describe the current state of the spatial configuration, and store these in the knowledge base; (3) convert the information stored in the knowledge base into a *.pl Prolog file; (4) run this file to be evaluated by SWI-prolog, returning the result of the inference process to the user. An overview of the complete system

[72] H1, H2, H3 represent the heights of three elements (rocks).

is presented below in Figure 5-6, and an example of the system's behavior using a concrete example is provided in Figure 5-7.

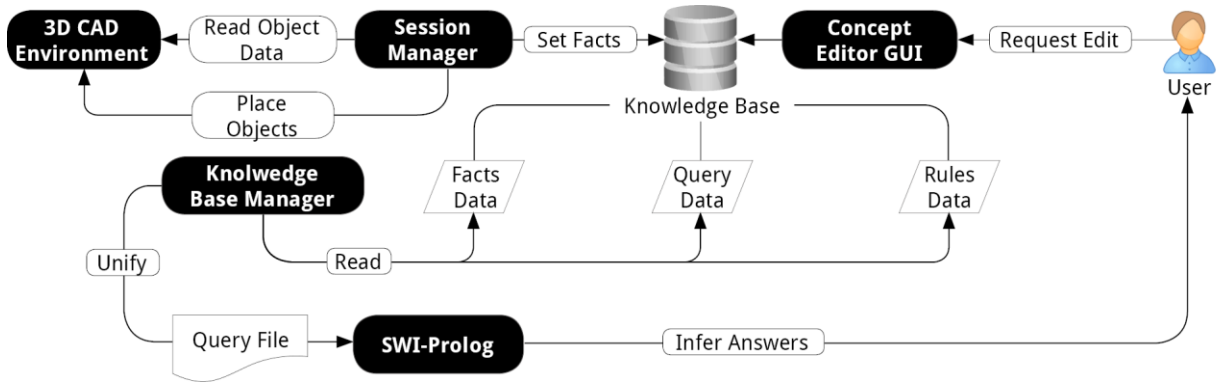

Figure 5-6 Overview of the implemented system.

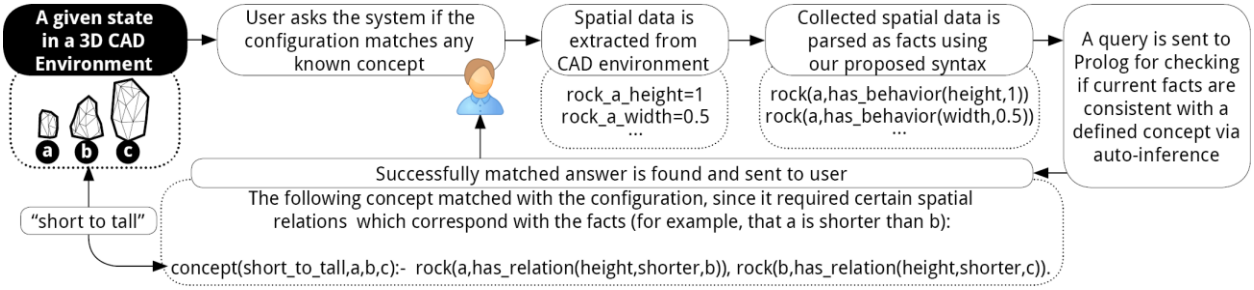

Figure 5-7 Basic concept-matching for a given configuration via our computational system.

5.5 Results and Discussion

5.5.1 Results

The ability of the system to store interpretations of structures was demonstrated by: (1) defining a set of basic dual and triad spatial relations and meanings, (2) utilizing the above relations to define a set of eight concepts listed in Table 7, (3) randomly generating spatial configurations consisting on three rocks, and (4) auto-evaluating these configurations using the inference system and recording the matching concepts given as output. Below are four examples for automatic matchings between configurations and concepts produced by the system, as well as a concise breakdown of each concept into lower-level entities (Fig. 5-8).

Table 7 The eight concepts defined for testing our implementation.

Number	Concept	Number	Concept
1	concept(parent_watching_brothers,A,B,C)	5	concept(teacher_and_students,A,B,C)
2	concept(mother_protecting_children,A,B,C)	6	concept(couple_with_pet,A,B,C)
3	concept(a_man_with_his_pets,A,B,C)	7	concept(a_mountain_range,A,B,C)
4	concept(parents_and_child,A,B,C)	8	concept(mountains_in_the_sea,A,B,C)

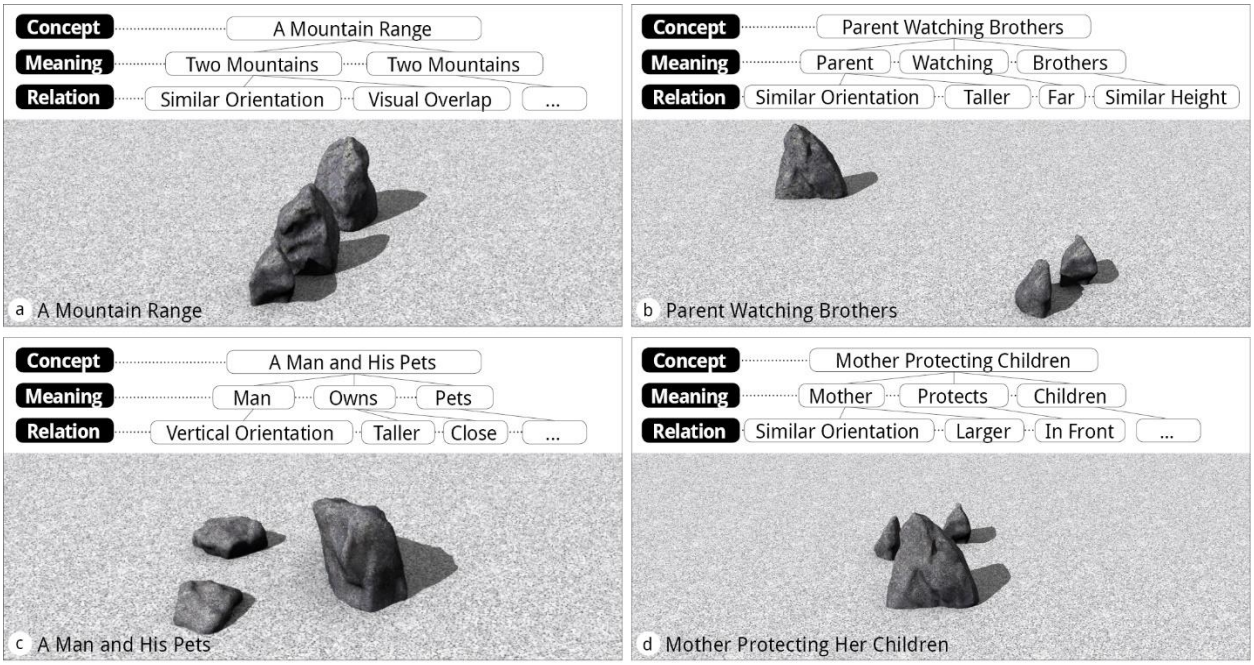

Figure 5-8 Examples of automatic matchings between a concept and a spatial configuration; (a) "a mountain range", (b) "parent watching brothers", (c) "a man and his pets", (d) "mother protecting children".

5.5.2 Evaluation

When evaluating our system, we: (1) explain how to interpret the results by referring to two matchings presented above in Figure 5-8, as representative examples; (2) compare it with several related systems which take a different computational approach.

First, in order to explain how to interpret the results, we focus on the configuration presented in Figure 5-8(a). This arrangement was matched with the concept "a mountain range", via identifying consecutive overlapping between elements, as well as similarity in orientation and differences in height. Visual overlap is the spatial expression associated with the meaning "two mountains", which served as the basis for defining the corresponding concept, along with the demand for a height difference. Therefore, when the system tried to match the

configuration with the concepts of "a mountain range", it identified two couples of "two mountains", resulting in a successful match with the presented configuration.

For further clarification, we now focus on the composition presented in Figure 5-8(b). This spatial arrangement was matched with the concept "parent watching brothers", by successfully matching its rocks with the three meanings of "parent", "watching" and "brothers". Each of these demanded a different set of spatial relations: the meaning "parent" is associated with having a similar vertical orientation, as well as with the demand for being taller, as fulfilled by the large rock in relation to the smaller ones. Further, the meaning "watching" is expressed by the large rock being positioned relatively far from these, and the meaning "brothers" is expressed by the height similarity between the two small rocks. All of these are then combined to generally match with the concept of "parent watching brothers".

Finally, while this study has taken a traditional AI approach, relying on logical inference as a means for relating meaning with spatial configurations, other researches have approached similar tasks from machine and deep-learning perspectives; this was done both via supervised processes and unsupervised processes. For example, Karimi et al. (2018) have used the well-known VGG-16 to detect the potential meaning of sketches (supervised learning), while Krijnen and Tamke (2015) used outlier detection to identify the core geometric characteristics of architectural elements such as walls etc. We believe that the key difference between the two approaches lies in the fact that, while machine learning-based practices can be seen as a means for feature extraction in this context, our approach is better seen as a form of "feature construction"; this is due to the fact that meaning is not merely detected in the configuration, but is also embedded in it by the designer via the creation of concepts. Each of these, however, is subject to natural limitations: logical inference demands a rigorous elaboration of each concept, supervised-learning requires many samples as a basis for training and unsupervised learning generally ignores important semantic attributes which enable the intelligibility of a categorization to a human designer. Consequently, we see them as rather complementary in attempting to relate structures with meanings. Accordingly, we aim to gradually integrate the other approaches into our work, as further discussed in 5.5.4.

5.5.3 Possibility for Generalization

With respect to the generalizability of the proposed framework - since the framework does not make any assumptions regarding the nature of the elements under discussion, it is generalizable, to a large extent, for a wide range of artistic or design domains consisting of spatial configurations (architecture, sculpture etc.), including those of a lower dimensionality (graphic design etc.). Yet, utilizing this framework in-practice in a different context would require a preliminary three-step process of: (1) determining which design elements are to be represented in the framework, (2) defining the domain-specific behaviors of these elements,

and (3) defining the relations between these elements which are domain-specific, given these behaviors. In implementing the framework for assigning meanings to spatial configurations in JRGD, we had followed a similar process of: (1) identifying the rocks as our elements of focus, (2) defining their behaviors such as dimensions, location etc., and (3) defining the relevant relations between them (size, distance etc.). Once this preliminary phase has been completed, we began assigning meanings to spatial configurations by combining multiple relations into single meanings. These in-turn were used to structure higher-level concepts, as presented.

5.5.4 Future Work

When discussing our future work, we would like to: (1) mention a possible future direction for further developing the proposed framework from the perspective of JRGD, (2) propose an additional future direction from a broader view which may be applicable for any other field in which the framework is implemented, and (3) conclude with a potential method for testing and verification of computational systems implemented based on our proposed framework.

First, in the context of JRGD, we have chosen to focus on rock elements, and have restricted our scope to a limited number of variables, i.e. mainly size and proportion. Considering the boundless variety of rocks in nature, incorporating additional rock features such as shape, texture and color, may enable us to dramatically expand the range of expression in our system. We aim to address this in our future research, possibly by integrating a feature-extraction module consisting of a convolutional neural network component, to auto-identify visual features effectively and phrase them as formal entities using our syntax. Moreover, while this study has focused on the selection and placement of rocks, it is both possible and desirable to further represent additional garden elements (gravel, moss etc.), in order to enable a more comprehensive description of the relation between spatial configuration and meaning in the garden. Indeed, while rocks undoubtedly serve as key elements in JRGD[73], many compositions receive their meanings from additional elements that are incorporated into the design.

When examining the framework and the implementation as a whole, another important aspect which calls for further research is the possibility of auto-formulation of concepts. Although manual formulation using a GUI is possible, it is a time-costly task which demands designers to reflect upon their conceptualizations, analyze them and then re-construct them using the proposed syntax. These burdens can be gradually removed from the process by further developing classification modules, to automatically derive formal concepts from existing design representations, guided by an input from the designer. This may be seen as

[73] Refer back to 5.2.1.

a type of auto-feature extraction, as already conducted in CAD/CAM processes (Henderson & Anderson, 1984; Liu & Chen, 2002).

Finally, an effective method of evaluating systems constructed using our framework would potentially consist of a human-in-the-loop-based practice. Since the framework aims to enable designers to communicate conceptual structures in a formal manner, it is important that new concepts will be verified either by their creator or by a fellow designer from a closely-related discipline, to confirm that the formal description and its spatial expression indeed match in a human-intelligible manner. Such verification processes may generally consist of: (1) selecting a concept to be examined, (2) auto-generating a large number of random spatial configurations, (3) matching the selected concept with these while filtering out irrelevant configurations, (4) presenting the subject with the remaining configurations which matched the concept for evaluating the adequateness of each via grading, and (5) using these grades to revise the original concept by adding further restrictions and demands onto the spatial configuration, to correspond with the configurations ranked highly by the testing subject.

5.6 Conclusion

A framework for storing metaphoric interpretations of structures was proposed, implemented and tested, in the context of JRGD. The framework enables to formulate and store high-level metaphoric descriptions, and their spatial interpretation, within concise linguistic expressions. These expressions (referred to as "concepts") are representative of metaphoric phrases which constitute the agent's vocabulary, used in interpretation. As such, their formalization facilitates the basis for knowledge representation of interpretation processes in design. This marks a step towards modeling interpretation activity, towards its implementation in computational design systems.

However, a realistic implementation of interpretation in a computational system demands the capacity to automatically assign our stored concepts, when designing. The next project explores the ways in which designers assign interpretations in practice, for modeling this process based on empirical data from design-cognition.

Chapter 6 Towards Modelling RI as a Situated Activity: A Case Study of JRGD[74]

In the previous chapters we have established a thought-framework for interpretation activity, and proposed a way to represent single interpretations within computational systems. This chapter aims to further our understanding of interpretation of structure, by observing how designers assign interpretations in-practice, when designing. Accordingly, it asks the following question: how can we model the assignment of RIs in-action, in conceptual design?

We record and analyze novice designers as they engage in interpretation, during a conceptual design task of designing a miniature JRG. In this, we focus on the common practice of drawing analogical mappings between structures and linguistic descriptions (i.e. the metaphorical interpretation). We then develop a framework for relating physical structures with linguistic descriptions in-action.

The main contribution of this study is a conceptual toolkit for systematically inquiring into cognitive phenomena, focusing on interpretation of structure in design. Since this toolkit is grounded in theoretical design models, as well as in empirical data from design activity, it both deepens our theoretical understanding of interpretation practices and enhances our ability to model them, for their implementation in artificial agents.

6.1 Introduction

In recent years there is a growing interest in constructing autonomous agents for conducting design tasks (Cai, Tang, & Li, 2019; Groenewolt, Schwinn, Nguyen, & Menges, 2018). Considering the potential of CAD tools to support conceptual design, research is conducted to develop computational systems for aiding in ideation and exploration (Jowers et al., 2008), encouraging conceptual shifts (Karimi et al., 2018) and more. Utilizing empirical data for formalizing practices of conceptual design can significantly contribute to further development of such systems.

In this study, we approach interpretation by integrating theoretical models of situated cognition (Clancey, 1997; Gero & Kannengiesser, 2004) with empirical data from design activity. Specifically, we focus on interpretation of structures of physical entities in spatial configuration design, in the context of JRGs, as a case study (Fig. 6-1). Simple interpretations

[74] Presented at the "Design Computing and Cognition '20" conference, December 2020; see (Kahlon & Fujii, 2020b).

are formally represented and their contribution to design activity is considered, from the perspective of situatedness in design.

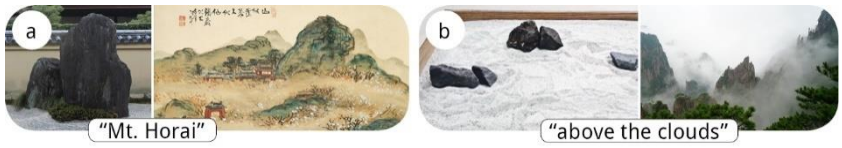

Figure 6-1 Spatial configuration and interpretation in JRG; (a) Mt. Hōrai in at Ryōgen-in, Kyoto & in a painting by T. Tessai; (b) composition by a subject & a photo of Yellow Mountain (Huangshan), China.

6.1.1 Spatial Configuration and Interpretation

The initial design phase of artifacts is often guided by a symbolic description, generated by the designer in attempt to mentally frame the design activity, and give it coherence as a whole (Hey & Agogino, 2007). Such descriptions, which often take the form of metaphor or analogy (Casakin, 2006), are the product of a continuous interaction between the designer and the artifact, as an act of interpretation in-action. The practice of producing and using these descriptions, referred to in this work as RIs, is fundamental to conceptual design activity (Goldschmidt, 1988).

6.1.2 Situatedness a Basis for Approaching Interpretation of Structure

Situated models for design (Gero & Kannengiesser, 2004), which are based on the situated approach to cognition (Clancey, 1997), consider design activity as an interaction between the external world and the internal world of the designer. Accordingly, they can potentially explain the emergence of conceptual interpretations from designers' interaction with their environment. We utilize this approach, and specifically the situated function-behavior-structure framework (situated FBS; Gero & Kannengiesser, 2004), to analyze the manner in which designers employ RIs during design activity.

6.2 Aim, Objectives and Scope

This chapter aims to shed light on the manners in which designers assign RIs, when engaging in conceptual design activity. Our main objectives are: (1) document conceptual design activity, (2) identify how designers assign RIs consisting of symbolic descriptions to ambiguous formations of physical entities, (3) construct a basic vocabulary for describing RIs from the perspective of situated cognition, and (4) utilize it to relate RIs with subsequent courses of action in design.

6.3 Significance

This study contributes to our understanding of visual interpretation in conceptual design, by relating RIs with their analogical basis, in the context of the design situation in which they emerged. Consequently, it may aid in: (1) constructing design agents capable of actively supporting conceptual design activity, for implementation in future CAD systems, by interpreting design representations in-action; (2) adapting current situated design models for describing visual interpretation activity.

6.4 Method

In accordance with our aim and objectives, we: (1) document an activity of designing a model of a miniature JRG; (2) extract analogies used to facilitate dependencies between design elements, and their underlying conceptual metaphors, by analyzing the design protocol; (3) identify key-elements in relating structure and interpretation across the three design worlds of the situated FBS framework (Gero & Kannengiesser, 2004), with the aid of other formal models for design; (4) discuss the contribution of these key elements to subsequent design activity.

6.4.1 Task and Setup

We devised a task of spatial configuration using a table-sized model of a JRG (Fig. 6-2). Subjects were asked to design a "garden" to their liking by selecting and positioning rocks from a small collection, with the constraint of refraining from stacking rocks (as in traditional JRG). The main design challenge lay in: (1) construing the task by defining the design theme[75]; (2) coordinating the selection and placement of rocks with one's interpretations. The task is situated in the sense that the designer develops all of the above on-the-fly, while interacting with the model.

[75] The subjects need to construe the meaning of "a garden"; similar to the work by (Goldschmidt, 1988) mentioned in 2.1.4.

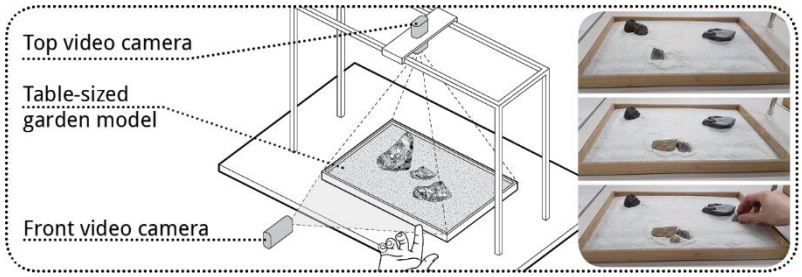

Figure 6-2 Experiment environment: setup and documentation.

The task was deemed suitable for the purpose of this study for several reasons, and mainly for: (1) JRGs' frugality, which renders them as a manageable environment for effectively exploring interpretation activity, considering the limited amount of design elements etc., and (2) the abstract and representational character of JRGs, which naturally encourages interpretation.

Sessions were generally capped at 30 minutes, to constrain the conceptual complexity involved in the design (however extended if the subject asked to continue in order to complete his/her design).

6.4.2 Data Collection and Processing

We employ the think-aloud method, instructing participants to design while expressing their considerations and deliberations, by voicing out their internal dialogue. Speech and actions are recorded using video cameras from two angles (top, front).

To facilitate designing in a think-aloud style, we preceded sessions with basic preliminary guidance. As explained by Rankin: "The importance of practice cannot be overemphasized. The subjects need to be introduced to the thinking aloud task before they can be expected to perform it" (Rankin, 1988, p.125). Accordingly, subjects were first asked if they are familiar with designing in this manner, and whether they have done it before. In cases where a subject did not have practical experience in the think-aloud method, we held a practice run with a simple task (for example, selecting a rock out of the collection which they like etc.). Instead of modeling (i.e. demonstrating) the manner in which they should think aloud, subjects were simply prompted to share more details, when their speech seems too-concise or rather reserved (Gibson, 1997). In such cases, we did not provide specific directions on how to do so, nor direct feedback on their performance.

Sessions were transcribed from the audio recordings. To establish a rich documentation, our transcriptions included literal utterances (by the subjects and the observer) and descriptive comments by the observer. Images presenting various states of the model were extracted from each video. Each design move, defined as an operation on knowledge (Goldschmidt,

2014), was represented by a single image. The audio-visual data was synthesized into text-image sequences, as a unified documentation of the design session.

6.4.3 Data Analysis Using State Diagrams

The amount of information relevant to interpretation activity, even in a brief design session, can be daunting. In order to understand the relations between events in design, it is useful to establish a visual representation system. Visualization aids in getting a better understanding of a design session, by exposing unnoticed connections between actions, decisions etc. Since we are concerned with relating the structure with its interpretation, we need to keep track of small changes made to the structure over short periods of time, along with changes in the interpretation. Tracking the design process in this manner, enables us to expose informative relations between structures and their interpretation.

Towards this aim, over the course of our research we have developed an assistive visual representation method which we term as "state diagram". State diagrams reflect:

- the objective state of the structure
- the assignment, aggregation, alteration and emergence of interpretations of it
- the relations between the above

A state diagram is generally composed of a collection of states, representing a single or several tightly-related subsequent design moves, extracted using protocol analysis. Each state is dissected into three layers, according to the three worlds of the situated FBS framework[76], so that: (1) the structure, i.e. the physical entities are represented at the 1st layer (external world); (2) interpretations and descriptions of the structure are represented at the 2nd layer (interpreted world); (3) intentions regarding future states of the design are represented at the 3rd layer (expected world). An example for a state diagram is given below.[77]

[76] By (Gero & Kannengiesser, 2004); refer back to 2.2.3.
[77] This analysis method is further discussed and demonstrated in chapter 6.

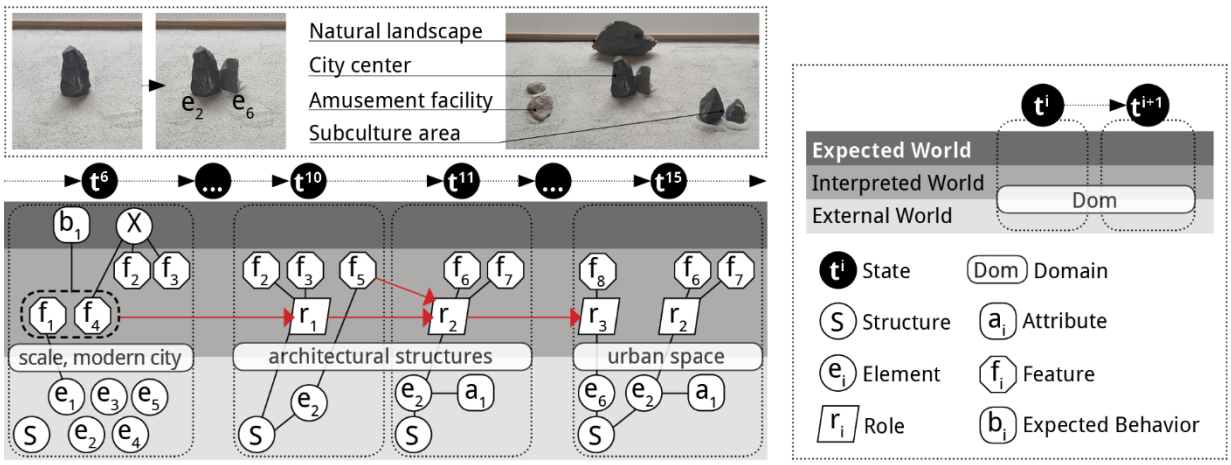

Figure 6-3 State diagram reflecting the relations between interpretation and structure; relying on (Gero & Kannengiesser, 2004); right: notation used in session analysis.[78]

When constructing state diagrams, we always analyze the activity chronologically, in the order of the events as they have occurred in practice. However, it is important to note that, currently, there is little importance to time as-such, i.e. to the actual duration of each action performed by the subjects. Accordingly, time durations are not graphically reflected in these diagrams. This is due to the fact that the same actions may be performed in different speeds by different subjects, depending on the subjects and their circumstances. Therefore, instead of focusing on time durations, we focus on the chronological sequence of events. This helps us in graphically mapping the manners in which the relations between the objective structure and its subjective interpretation are co-developed throughout the session.

6.4.4 Participant Selection

A total of 10 individuals were recruited for conducting the deign task. All participants hold at least a bachelor's degree in a visual design discipline (for example, Architectural Design, Industrial Design etc.). With respect to the skill level of the participant - most sessions were conducted with novice designers, with minor practical experience in design offices or in architectural firms.

It is important to emphasize, however, that the task chiefly aimed at eliciting interpretation in the context of conceptual design in general, to enable us to understand the basic structure of this activity. From this perspective, neither superior design experience nor specific background knowledge about JRGD were necessary. Therefore, while the study could

[78] Expanded upon in 6.7.

theoretically benefit in future stages from including highly-skilled designers as participants, the chosen skill level of the participants is appropriate for this study.[79]

6.5 Identifying Interpretations and their Analogical Basis

6.5.1 Interpretation and Analogy

As previously mentioned, a powerful strategy by which designers structure their understanding of design tasks is via the usage of conceptual descriptions, such as RI. One basis for effectively assigning such descriptions is the existence of similarities between attributes and relations among the design elements and those among other entities, belonging to a domain which the designer is familiar with (source). This enables to intuitively project these onto the existing structure (target), as a form of analogy-based interpretation.

Furthermore, as similarity-based mappings between objects or entities, analogies serve as the basis for analogical reasoning. Analogical reasoning enables us to extend our knowledge from a familiar domain (source) into a less-familiar one (target), via retrieving such mappings and utilizing them for making further inferences (Holyoak & Thagard, 1996). Accordingly, they can serve as drivers for reasoning in interpretation.

6.5.2 Three Levels of Analogical Mapping

Analogical mappings are generally classified into three types, based on the level at which similarity is identified: attribute mapping (AM), relational mapping (RM) and structure mapping (SM[80])(Gentner, 1983; Holyoak & Thagard, 1996). We rely on these for extracting and analyzing analogical mappings from design sessions. Below is a brief explanation including a simple example for each.

In AM, two things are deemed similar owing to a shared attribute, for example: an orange and a basketball are both round and thus similar in this respect. In RM, similarity is identified between relations, e.g. on a higher level, for example: a bear cub and a kitten are both younger than their parents, and therefore share this relation. In SM, similarity occurs on an even higher level of abstraction. Gentner provides the example of similarity between a hydrogen atom and the solar system - both contain an element which revolves around another (Gentner, 1983).

[79] In fact, this also benefitted us by enabling to constrain the complexity of the activity to some extent. Additionally, see the important related work by Schön, which relied on participants from a similar skill level (Schön, 1993).
[80] Alternatively referred to as “system mapping”.

6.5.3 Extracting Interpretations from Design Sessions

On the basis of the above classification, RIs were extracted from design sessions via protocol analysis, while consulting the visual documentation. We now present several interpretations at varying levels of complexity, each accompanied by the analogy employed at the time of formation (Fig. 6-4). These are then summarized in Table 8, which also provides a simplified formalization for possible analogical mappings corresponding with the RI.

Interpretation 6-4(a) presents a rock referred to by a subject as "an old storyteller". Old age was attributed to the rock owing to its rugged surface form, resembling the rough surface of an elderly person's wrinkled skin, i.e. a simple AM was employed.

In 6-4(b) we see a slightly more complex RM, under which the larger rock is interpreted as "a background" for the smaller one, justified by their spatial relations of front and back. In the accompanying image, a large bush serves as a "background", for a smaller one.[81]

Finally, 6-4(c) relies on a SM in which the similarity between the target and its source occurs on the level of human experience. Visitors to Honpukuji Temple (explicitly referred to by the subject) begin by climbing a staircase bounded by a narrow hall, which then leads to a vast open space. This contrast elicits a feeling of surprise and discovery, which the subject tried to embed in the design by placing a row of similarly-sized rocks leading to a significantly larger one.

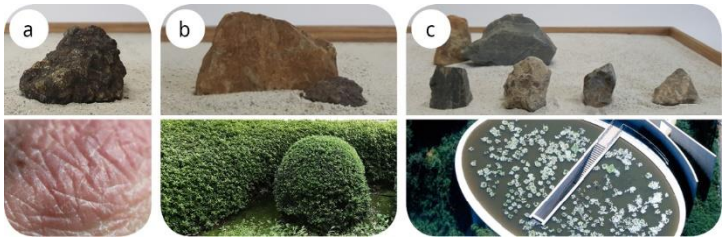

Figure 6-4 Examples for RI in design and possible associated sources: (a) "old person", (b) "a background", and (c) "journey of discovery". [82]

Interpretations, however, are not merely passive labels attached by designers to the artifact on analogical (or any other) grounds. They are, in fact, powerful drivers for developing a conceptual understanding of the design activity, by helping to structure the relations between design elements (Hey et al., 2008). This is highly noticeable in cases where the analogy

[81] While this mapping is established based on the existence of simple spatial relations, it may be further elaborated by finding additional similarities between the source and target. For example, the flatness of the larger element may suggest the flatness of a canvas, as a background for a painting etc.
[82] See Table 8 for further details; sources: (c) Honpukuji Temple, Tadao Ando, Awaji island, Japan (japan-magazine.jnto.go.jp).

exposes a hierarchical order, which guides the designer's understanding of the current situation, as discussed in the following section.

Table 8 Interpretations & their supporting analogies.[83]

Item	Interpretation	Focused Aspect	Analogical Mapping	Type
a	"an old storyteller"	apparent age	*rough-texture(old-person) →rough-texture(rock-a)*	AM
b	"a background (object)"	visual composition	*behind(background,foreground) → behind(rock-a,rock-b)*	RM
c	"journey of discovery"	user experience	*journey(user,rock-sequence) → journey(user,space-sequence)*	SM

6.6 Relating Structure and RI via Element Dependencies

Interpretation by analogy often invites attributes and relations from external reality, into the designer's internal world. By projecting these onto the design elements (whether explicitly or implicitly), the designer begins to conceptually understand the design as a unified construct, which corresponds in some manner to constructs in the external world. The internal construct may then be further interpreted and reasoned about, based on the dependencies between its elements.

We first introduce the notion of design worlds in the situated FBS framework, as a basis for analyzing interpretation activity. This is followed by concrete examples of interpretations from design sessions which are structured hierarchically, as well as the contribution of these to the designer's understanding of design activity.

6.6.1 Hierarchical Relations in Analogies Used by Participants

We begin by extracting and analyzing simple analogies which include a notion of hierarchy. Several examples, used by participants during design sessions, are provided below in Figure 6-6.

In what sense are these of a hierarchical nature? While in each RI different relations occur between the design elements[84], in all underlie conceptual superiority-inferiority relations, reflected in the dependencies of certain elements on others (Kahlon & Fujii, 2019b). These can be identified from various perspectives: for example, in 6-6(a) children may depend on the old man for guidance (social), while in 6-6(e) the growth of petals depends on the existence of the body of the flower (part to whole).

[83] This is complementary to Fig. 6-4.
[84] For example, 6-6(a) entails an age difference, while 6-6(e) a part-to-whole relation.

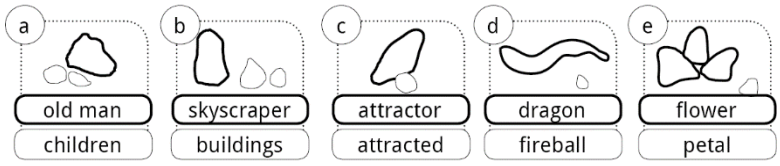

Figure 6-5 Interpretation via analogy containing a hierarchical component.

The identification and selection of some dependencies rather than others during RI activity is related with the notion of aspectual shape (Searle, 2004), and is beyond the scope of this study. It is important to emphasize, however, that regardless of a specific aspect a designer may focus on, utilizing an analogy of a hierarchical nature results in the projection of roles upon the design elements. These roles help to further structure design activity, as explained in the following sub-section.

6.6.2 Structuring the Interpreted World via Roles

Since RIs (such as the above) determine the meaning of design elements for the designer, they also determine their potential contribution to the design activity, from the internal perspective of the designer. Consequently, they are essential building blocks of our interpreted world. Therefore, relating RIs with their grounding in the external world can aid in understanding and describing the interpreted world. This can be done on the basis of hierarchical dependencies, revealed by metaphoric roles.

Before proceeding, however, it is important to further elaborate the notion of RI: (1) the complete symbolic description assigned to the composition, which generally frames the theme for the design, will be referred to hereafter as "RI"; and (2) the function description projected onto a physical design element, by relating it with a referent external to the design, will be referred to as "role" (see Table 9).

Now, consider the example in Fig. 6-7 below, in which the designer had interpreted a two-rock composition as "rock with plants growing under it". Under this RI, one rock (e_1) is simply seen as a rock (r_1), while the other (e_2) as plantation (r_2) growing under the former. The rocks in the external world thus correspond with roles in the interpreted world.

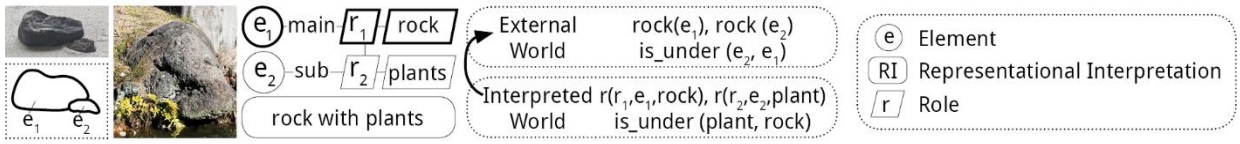

Figure 6-6 Correspondence between entities in the external and interpreted worlds.[85]

This simple correspondence, however, goes beyond mere denotation. Brereton has pointed out the importance of "negotiation" between material and abstract representations in conceptual design, which provides designers with opportunities for further structuring current representations (Brereton, 2004).[86] Each description assigns an element with a role, which is to be conceptually fulfilled by its bearer. Fulfillment of a role may be seen as maintaining certain relations with other elements, as to correspond with their external world referents. This can be understood on two different levels: first, the interpretation imposes certain spatial relations between the elements. For example, continuing with Fig. 6-7, once the small rock has been assigned with the role of "plantation growing under…", it is expected to sit beneath the larger one, and perhaps close to it. More fundamentally, however, we can uncover a powerful conceptual metaphor, which underlies the hierarchical relations resulting from the assigned roles, and thus guides design activity. Hierarchy implies dependency, and dependency implies control. Accordingly, moving the larger rock for some reason will entail considerations regarding its subordinate "plant" rock. The dependency from the internal world is thus translated into dependency in the external world, and the two worlds are linked by metaphoric roles.

6.7 Modelling RI in-Action from a Situated Perspective

Smith and Gero note that, when perceiving, agents interact with focused objects to construct interpretations regarding their potential, rather than their current identity or denotation (Smith & Gero, 2001). This is, of course, highly related with the act of "seeing as", which served as a basis for the discussion so far. Objects' potentials, reflected by their interpretation, may be further described as their possible contribution to the design process. This potential is determined by a combination of objective attributes and relations as well as subjective impressions of these, i.e. via interaction between the external and interpreted worlds. Therefore, RI can only be fully accounted for by representing both the former, the latter, and the relation between them.

[85] On the basis of the situated FBS framework by (Gero & Kannengiesser, 2004).
[86] And thus, providing opportunities for structuring their interpreted world.

We propose a structured approach for representing and analyzing RI in design, based on empirical data from design activity, as well as theoretical models for situated design (Gero & Kannengiesser, 2004) and analogy-based design (Qian & Gero, 1996). We begin by defining key terms (Table 9) and provide an example for the graphical notation used in our analysis (Fig. 6-7).

Table 9 Important terms for modeling RI activity and their definition.

Term	Definition
Element	An indivisible physical part of the design, or its representation[87]
Attribute	A single property of an element[88]
Expected Behavior	A behavior which is to intended to be brought about by design activity[89]
Role	Interpretive function description of an element as defined by a RI
Feature	Descriptive expression assigned to an element or its role in the course of design by the designer, in an explicit manner
Domain	The domain of discourse which is implied by the protocol
State	A segment of the design session after which change is observed

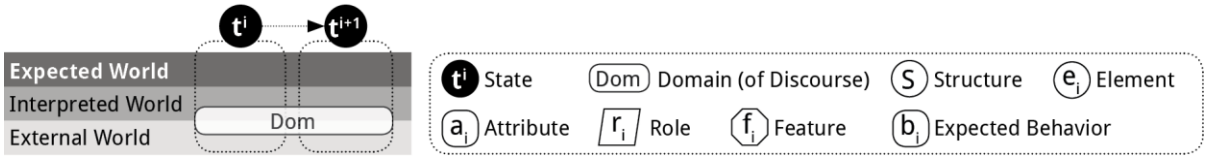

Figure 6-7 Notation used in analysis; left: a transition between two states[90]; right: session analysis legend.

6.7.1 Situated Interpretation and Action

We now present and discuss several important aspects of interpretation activity, from the perspective of situated design. We focus here on three operations named: role assignment, constructive elaboration, and detachment.

Role assignment consists of naming design elements as to denote referents external to the design. In Fig. 6-9 the subject began by considering size ("I will pick a smaller one") with the goal of creating "a small place for people to walk around", followed by the suggestion of a general domain of interest ("I really like modern cities"). The structure was thus assigned with the role of a city (r_1), which prompted a size-based selection ("pick something bigger") of a thin element (e_2) to serve as a "skyscraper" (r_2), also based on a proportion attribute (a_1). Consequently, an element (e_6) was added as a "smaller building" (r_3).

[87] Similar to "primitive element" in (Qian & Gero, 1996).
[88] Similar to attribute in (Qian & Gero, 1996)
[89] As in the situated FBS framework.
[90] Notice that these are the worlds of situated FBS (Gero & Kannengiesser, 2004).

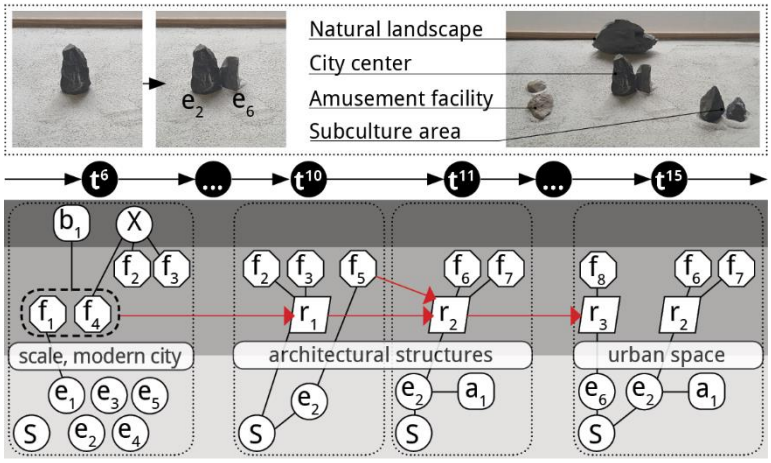

Figure 6-8 Role assignment; e2 and e6 are interpreted as a skyscraper and a building, accordingly.

Table 10 Complementary to Figure 6-8; Selected states and their representation.[91]

State	Utterance	Representation
t6	"I will pick a smaller one… I really like very modern cities like Tokyo and New York"	f1=feature(e1,small) f4=feature(X,metropolitan)
t10	"to symbolize the image of city… I would pick some bigger thing to help create…the framework"	r1=role(S,city) f5=feature(e2,bigger)
t11	"it looks like…how to say…a building, a tall skyscraper"	r2=role(e2,skyscraper) a1=attribute(e2,proportion)
t15	"and also…some smaller ones beside the skyscraper"	r3=role(e6,building)

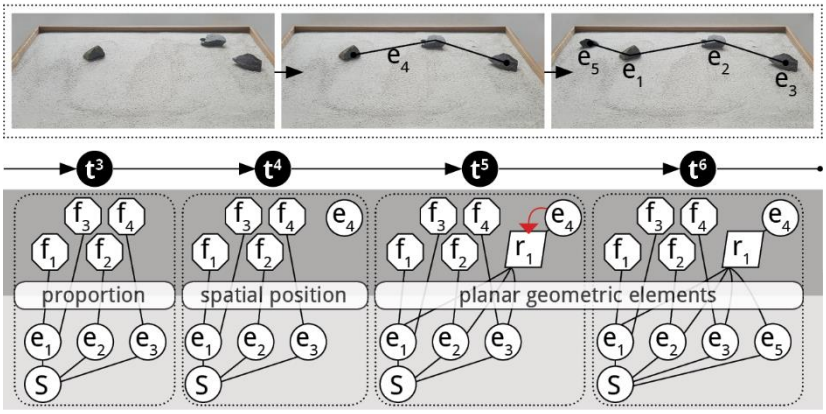

Figure 6-9 Simultaneous roles assignment; role projection from gestalt perception.[92]

[91] The full transcript for this session is given under A.2.3 in the Appendix.
[92] The full transcript for this session is given under A.2.2 in the Appendix.

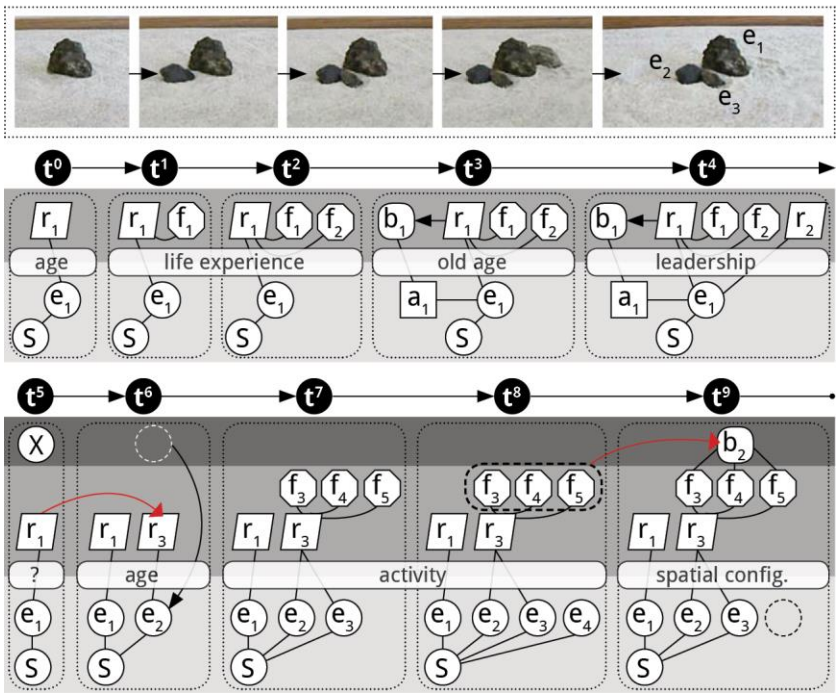

Figure 6-10 RI elaboration based on initial roles assigned to an element.

Table 11 Complementary to Figure 6-10; selected states and their representation.[93]

State	Utterance	Representation
t^0	"like an old man"	r_1=role(e_1,old-man)
t^1	"has some stories to tell"	f_1=feature(r_1,has-stories)
t^1	"maybe he has suffered a lot"	f_2=feature(r_1,suffered)
t^3	"we can see…small bumps"	b_1=behavior(a_1,bumpy)
t^5	"and maybe some…"	X=?
t^{6-7}	"…(these are the) next generation around him…the children are listening to his stories…they are sitting around"	X= e_2; r_3=role({e_2,e_3},children); f_3=feature(r_3,next-generation); f_4=feature(r_3,sitting); f_5=feature(r_3,listening)
t^8	"…they should be face to face"	b_2=behavior(r_3,face-to-face)

In Figure 6-10 we provide an example of role assignment for multiple elements, induced by gestalt perception. The subject saw a "connecting line"[94], which then prompted the interpretation of each rock as a "dot" (e_1, e_2, e_3), resulting in the selection and addition of an element to continue the perceived line (e_5).

[93] The full transcript for this session is given under A.2.1 in the Appendix.
[94] Notice that this element only exists only in the interpreted world.

After assigning roles to design elements, it is also possible (and in fact common) to extend the interpretation, by constructively elaborating roles for the other elements as well, as a basis for their selection and positioning. This can be seen in the short segment, given above in Figure 6-11. The designer deemed the first rock (e_1) as "old man" (r_1), and expanded its description by adding that "it has some stories to tell" (f_1) etc. These interpretative descriptions, grounded in the designer's RI by the AM[95], have directed the next course of action - the designer chose to add rocks (e_2,e_3) as "children" (r_3) to "listen to his stories", and finally determined they should be "face to face" (b_2), thus removing an incompatible element, which was not "facing" the old storyteller (e_4).

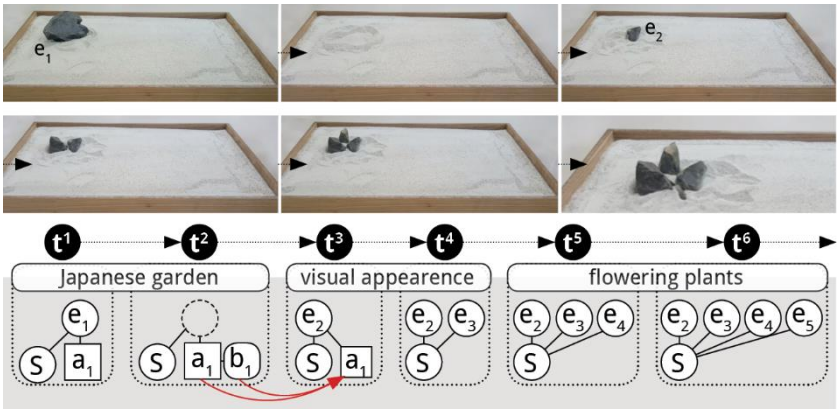

Figure 6-11 "Flower and fallen petal"; a simple example of attribute detachment.[96]

Detachment deals with the intuitive transference of entities (attributes, features, roles etc.) from one element to others, during the design process. As an example, we present Figure 6-12 in which the initially selected rock (e_1) was removed, only to be replaced by a different rock positioned in the same location (e_2). The original rock helped the designer to establish the position for the first element in the space, but could not stand due to its form. Its position attribute was transferred to the next element, which served as the first element in the actual final composition that represented a flower.

6.8 Discussion

We have attempted to systematically approach RI activity by identifying entities which lie at its core. These entities were then used to model design sessions, in a manner which enables to trace some of the contributing factors for the assignment of different RIs. We now focus on

[95] The mapping here can be formulated as [rough(rock-surface)→rough(elderly-skin)]
[96] The full transcript for this session is given under A.2.7 in the Appendix.

the relevance of the three phenomena, presented in the previous section, to understanding interpretation in-action.

First, when discussing the issue of concept formation, Gero asks "where do concepts come from?" (Gero, 1998a). Analogically, we can raise the following important question: where do RIs come from? Viewing interpretation as an act of attributing meaning to design elements, and considering the importance of metaphoric roles for RI, it may be useful to first attempt to explain how metaphoric roles are attributed. As shown in Fig. 6-9, while roles often have an analogical basis, their emergence in the design process cannot be accounted for merely on the basis of analogical relations, but only as an interaction between different design worlds. In this specific case, the role emerged at least as a product of: (1) the focused domains of discourse, i.e. scale, metropolitans etc.; (2) the decision to start with a large element, "to set the framework"; and (3) the form of the rock. This points to the potential of expanding the situated FBS framework to include discursive factors contributing to the design. For example, the current domain of discourse, which helps in shaping the course of action, and thus may affect or trigger different processes and transformations.

Second, Clancey (1997) maintains that one core phenomenon in situatedness is the reassignment of meanings, as a result of perceiving changes in the environment. Constructive elaboration thus enables the extension of interpretation over a period of time, during which reconsideration and revision can take place. This is consistent with the emphasis on the importance of time extension in perception processes, as propagated by Neisser (1976). For example, in Fig. 6-11 the physical properties of the rock first served to construct a spontaneous RI ("old man") which was further sophisticated by elaborating suitable roles for the other elements ("children listening to his stories"). This was not done in a strict serial manner, but rather as an act of coordination, characterized by a simultaneous adjustment of the RI and the spatial relations. Hence, both the structure and the RI were conjointly conceived and reconceived.

Third, the phenomenon of detachment may reflect designers' tendency to try and maintain positive aspects of a structure, while essential changes are made to it. This is rendered possible by projecting properties of certain elements onto others, as an act of establishing an "element lineage", linking generations by inheritance[97]. The subject's attachment to the initial placement in Fig. 6-12 resulted in its "survival", despite other inevitable changes (i.e. replacing an unstable element).

All of the above point to the strong potential of analyzing RI activity from a situated perspective, which enables to understand complex events in design activity as a result of

[97] We thank Barbara Reicher for suggesting this metaphoric description of the phenomenon.

several, lower-level factors. We believe that further inquiry into recurrent patterns in interpretation, based on the proposed modeling approach, can lead to identification of important processes which are essential for RI activity. This may aid in formalizing such processes to be used in intelligent computational design systems.

6.8.1 Implications

The main implications are now briefly discussed. In recent years, research is conducted to develop computational design support systems which can effectively propose automatic interpretations to visual content. Such systems can benefit from the identification of key-entities and phenomena which characterize interpretation as a situated activity. The former can be used for creating explicit representations in a knowledge base, to enable further reasoning; the latter for considering new interpretation strategies, based on empirical data from designers.

The system developed by Karimi et al. proposes alternative visual interpretations for sketches made by a designer (Karimi et al., 2018). In a related manner, the system by Jowers et al. enables recognition and manipulation of sub-shapes, as a basis for re-interpretation (Jowers et al., 2008). These systems, for instance, may be further developed to consider potential roles of design elements, as well as deeper sets of relations between them, as a basis for interpretation in conceptual design. Such efforts may be assisted by existing research on the role of metaphor and analogy in design (Casakin, 2006; Hey et al., 2008), and specifically on formally relating metaphoric descriptions with spatial configurations (Kahlon & Fujii, 2019).

Furthermore, in other design fields such as engineering design, analogy is often used for concept generation, by locating “functionally relevant” (Fu et al., 2015) sources, to inform or inspire the designer regarding the task at hand. Given that the designer is reasoning with respect an existing structure, the ability to locate relevant sources by analogy is restricted by the manner in which the structure is encoded (Linsey, Laux, Clauss, Wood, & Markman, 2007). Including high level descriptions (when encoding), such as metaphoric roles of elements, can enhance our ability to relate sources with targets; by enriching the description of the structure with possible interpretations, as to identify similarities on a conceptual level.

6.8.2 Limitations

We mention several important aspects of the work which demand attention in the next steps of development, the first being the complexity of the structures under consideration. In contrast with the previously mentioned framework by Qian and Gero (1996), which discusses complex elements (referred to as “substructures”), we currently account only for interpretation of single elements (“primitives”) and thus only deal with relatively simple structures. However, while JRG design activity does not enable actual physical attachment

between elements to create compound objects, it is possible to consider compositions of several rocks as substructures, once they are visually grouped in a certain manner (Van Tonder & Lyons, 2005). Complexity may be further considered at the element-level as well, via enabling representation at different degrees of abstraction, encouraging different RI (by increasing the variety in our rock collection, or by repeating the task with different design elements).

Additionally, it is important to acknowledge a knowledge gap which should be filled, in order to implement our insights in artificial agents. Although computational systems can draw on this work for enhancing their ability to assign interpretation[98], it is necessary to go beyond the identification of these, and towards modeling their complex interactions, which are an essential part of how designers engage in RI.

6.9 Conclusion

A systematic approach for studying the assignment of interpretations in design was proposed and demonstrated, via conducting and analyzing a simple design task in the context of JRGD. Our approach enables to map important relations between structures and interpretations, as they emerge and change, when reasoning in design. Consequently, it enables to track and identify various factors which drive the assignment of interpretations (as reflected in our analysis and discussion of interpretation-related phenomena). It can thus be regarded as a valuable tool for drawing insights from design-cognition, towards enabling artificial agents to assign interpretations during design activity.

However, tracking specific contributing factors[99] is insufficient for describing how designers navigate through and reason in interpretation activity. This is due to the fact that these are embedded within subjective mental frames, which underlie (and thus strongly drive) our reasoning processes. Therefore, to truly understand how designers assign interpretations, we need to try and take their perspective of the design process. The next project deals with this challenge.

[98] By integrating the various factors that we have identified as contributive to interpretation.
[99] Such as the domain of discourse, physical properties of elements etc.; refer back to 6.7.

Chapter 7 Interpretation as an Act of Worldmaking

In the previous chapters we have laid the foundation for systematically approaching interpretation activity by: (1) providing a theoretical thought-framework for its description, (2) proposing a formal framework for representation of interpretations, and (3) suggesting a practical modeling approach for inquiring into how designers assign interpretations, when designing. In this chapter, we further deepen our inquiry by studying the ways in which interpretation activity itself is subjectively experienced by the designer. Accordingly, we approach the following question: how can we model the designer's perspective during the assignment of RIs?

As previously shown, when interacting with structures [100], designers often rely on metaphorical descriptions as interpretive devices. Interestingly, these may result in the formation of loose narratives which frame the task at hand, utilized as powerful devices for gaining high-level conceptual understanding (and thus control) of the design process. As such, these narratives bear important information about the designer's perspective, when designing. This chapter proposes a way to model this practice of forming interpretive narratives, by harnessing state-of-the-art models for situated design, as well as theories from discourse analysis and the philosophy of mind.

The task of designing a miniature JRG is repeated, this time in teams. We observe how subjects work in couples and weave simple narratives, as interpretive frames, and introduce an approach for modeling this practice, as a means for looking into the designer's mental world. This results in a new view of interpretation of structure, as an act of world making. We thus propose a notion that we term as "narrative worlds" – interpretive worlds used to gain high-level control of the design process. This notion not only extends our reach beyond the components and into the dynamics of interpretation, but also opens a window to the mental image held by the designer, which underlies and thus shapes the design process. As such, it advances our understanding of the subjective dimension of interpretation activity, towards the enhancement of artificial agents targeting interpretation.

[100] The reader should keep in mind that by "structure" we refer either to the artifact or its representation.

7.1 Introduction

In 1979, Jane Darke pleaded for embracing subjective aspects into the study of design processes (Darke, 1979). The plea was answered, resulting in research work which closely examined design from the perspective of the designer. One subject of study in which subjective factors were acknowledged was the study of interpretation.

Goldschmidt, for example, has demonstrated how architectural design students construed the same task in very different manners, when designing a small residential unit that needed to conform to the idea of a "cube" (Goldschmidt, 1988). Another key-example can be found in the work by Schön, who proposed that different designers inhabit different "design worlds", shaped by their individual knowledge and design experience (Schön, 1988).

Our work aims to further these efforts of (to borrow Darke's phrase) "looking into the designer's head" (Darke, 1979, p.43). Widely-used approaches for mapping design processes, such as Linkography (Goldschmidt, 2014), provide us with tools for describing design from a third-person perspective. However, if we are to fully understand interpretation activity, these must be complemented by methods which inquire into the designer's first-person perspective.

We take the general view of interpretation as designers' attempt to make sense of the current situation, in-line with Krippendorff's description of design as a process of 'sense-making' (Krippendorff, 1989). A powerful form of sense-making in design relies on the usage of metaphors. Conceptual metaphors (Lakoff & Johnson, 2003) enable designers to gain high-level control of the design process (Hey & Agogino, 2007) by conceptually framing tasks under a unifying theme, thus suggesting new perspectives on design situations (Casakin, 2006).

The full power of metaphor comes into play when it serves as the basis for weaving metaphorical narratives. Narratives can aid in managing complex situations, by enabling us to frame them in an intelligible, memorable manner (Bowman & Crawford, 2018). Considering that design regularly deals with complex situations, it is important to study how may narratives be used as interpretive conceptual tools, to navigate the design process.

As sense-making in design is tightly-linked with the important notion of synthesis (Kolko, 2010a), we study how designers employ narratives to synthesize observations, judgments, insights etc., into coherent wholes. Our main objective is to examine the manners in which interpretations form and develop via what we call "narration-in-action", to deepen our understanding of the designer's internal perspective of the situation.

We observe designers as they make sense of small sets of physical objects in real-time, during a simple design task. We then utilize recent frameworks for modelling design processes (Gero & Kannengiesser, 2004), along with theories in discourse analysis (Fauconnier, 1994) and in

the philosophy of mind (Searle, 2004), to model interpretation as a process of linking external and internal reality, via narrative.

The main contribution of this chapter is our notion of "narrative worlds" – these are environments in which the mental content involved in interpretation activity can be organized and visualized. In these worlds, to borrow Uexküll's phrase of his magic worlds - "…fantastic phenomena mingle with the perceptually given things" (von Uexküll, 1934, p.67). This new notion extends our ability to map and understand the design process, through the eyes of the designer.

7.2 Background

7.2.1 Narration-in-action

Bruner has proposed a basic distinction between two modes of thinking and constructing reality: the "logico-scientific" mode (grounded and rigorous, strives for verifiability) and the "narrative" mode (rather buoyant and free, aims at plausibility or believability) (Bruner, 1986). This work looks at design through the lens of the second. How do designers utilize this thinking mode in their work?

The narrative mode of thinking results in the production of narratives. To facilitate further discussion, basic concepts from narratology are introduced. A narrative may be defined as "The recounting of a series of facts or events and the establishing of some connection between them" (Childs & Fowler, 2006, p. 148). Notice that this definition is useful for discussing narratives in design, as they often tie objects and events in a loose manner, without abiding to a strict beginning-middle-end structure (Patrick, 2006). According to Chatman, a narrative is fundamentally composed of a "story" and a "narrative discourse". The former is concerned with contents (setting and characters referred to as "existents"; actions and happenings referred to as "events"), while the latter refers to the form in which it is communicated. Narrative discourse is further elaborated into "process statements" (those which assert an event) and "stasis statements" (those which assert the existence of an object in the story). Finally, as communicative acts, narratives have both senders (the author, for example) and receivers (Chatman, 1975).

In design, narratives can be used to bridge the basic processes of analysis and synthesis (Patrick, 2006). Considering the tight link between synthesis and sensemaking in design (Kolko, 2010b), as well our natural ability to create narratives and intuitively understand them, narrative-making seems as an indispensable cognitive device for navigating through design activity. Furthermore, the value of narratives extends well beyond the individual designer, as pointed out by Lloyd: "storytelling appears to be a central mechanism in the

development of a common language in design teams" (Lloyd, 2000, p.357). In short, shared narratives can facilitate the joint development of design solutions (Rao, Moore, Udekwu, & Hartmann, 2020). One of the ways in which narratives aid in sensemaking and navigating design processes is by "framing" the activity. Dorst describes framing as the generation of a "hypothetical way of looking at the (design) problem" (Dorst, 205, p. 25). How does this process take place?

According to Krippendorff, the process of sensemaking consist of a circular movement between: (1) sensing, and (2) imagining a hypothetical context, for attributing meaning to the sensed data (Krippendorff, 1989). Kolko explains that these efforts of "finding clarity in chaos" (by synthesizing data into a coherent understanding) are often hidden from external observers, as design synthesis is commonly done "in the head" (Kolko, 2010, p. 15). This poses difficulties for understanding how designers engage in interpretation and framing. In their work on storytelling in design, Beckman and Barry have explained that designers generally engage in this practice in two phases: (1) capturing the current situation "as is" within an initial frame, which serves as a hypothetical context; (2) improving upon the initial frame via reframing, which opens new possibilities for seeing the design problem (Beckman & Barry, 2009). The ability to do so largely relies on our human capacities for interpretation.

Interpretation can be seen as a key process in design, spoken of by Goldschmidt as the "single most important force in the shaping of design solutions"(Goldschmidt, 1988, p. 235). In this research, interpretation refers to the assignment of symbolic (verbal) descriptions to physical objects, when letting one object stand for another. Designers often regularly engage in such activity, when working with design representations.[101]

This interpretive practice is facilitated by our ability to take objects as "epistemically transparent", in the words of Liddament, i.e. to look beyond them, and grasp what they picture, or represent (Liddament, 2000). When successful, we say that the designer engages in an act of "seeing as", a concept introduced into design theory by Goldschmidt in the context of architectural design sketching (Goldschmidt, 1991), and on the basis of Wittgenstein (Wittgenstein, 1958). It is often the case that interpretations induced by such acts are done via metaphor, used to draw conceptual mappings to other objects or domains. Since these enable high-level control of design activity (Hey et al., 2008), they comprise an important part of our cognitive apparatus for successfully coping with design situations. Metaphoric interpretation here means that the designer assigns the artifact (or its parts) with certain descriptions, so that the literal meaning of the utterance is different from the intended meaning (Searle, 1990).

[101] For example, in architectural design a cardboard box may stand for a building.

We model the practice of gaining such control over a simple design task, by observing designers as they interpret small collections of physical objects, serving as design representations. Architectural designers work in couples and weave shared narratives, to make sense of the design process, as they go, which can be thought of as "distributed sensemaking" (Weick, Sutcliffe, & Obstfeld, 2005). When they form such narratives in real-time, we say that they engage in "narration-in-action". Narrative here refers to the totality of metaphorical interpretations and the manners in which they interrelate (story). The designers are seen at once as both the senders and receivers of a narrative which is weaved on-the-fly, via verbal utterances (narrative discourse).

7.2.2 Interpretation as World Making

Inspired by the work of Nelson Goodman (Goodman, 1978), Donald Schön, suggested to approach designers' work with design representations as an activity of world making (Schön, 1988). According to Schön, the interpretation of representations involves the formation of worlds: "...prototypes are inherently ambiguous, subject to multiple readings, each of which involves the construction of a different design world" (Schön, 1993, p. 66). Since narration-in-action is an interpretive activity, which takes place when working with design representations, we rely on his work as a springboard for our inquiry.

In Schön's account, design worlds are dynamic constructs born out of the designer's interpretation, and include both design representations and our concepts of them. Their basic constituents are:

- elements (specific physical parts of the artifact being designed, or their representation)
- relations (between the elements and their parts)
- groupings (spatial gestalts unifying perceived objects)
- meanings (interpretations attributed to the elements, given certain relations, groupings etc.)
- types (prototypical sources of design knowledge; e.g., "basilica")
- rules (derived from the designer's types and used for reasoning; e.g., "rule of thirds")

Schön refers to his objects of study as "worlds", implying that he has a whole in mind, found behind these constituents. However, he does not tell us how the parts, taken together, form these worlds as wholes.

To understand what constitutes a world, we turn back to Goodman's famous account of worldmaking (Goodman, 1978). Here, worlds are seen as products of language (in its broadest sense), which serves as their primary substance: "We can have words without a world but no world without words or other symbols" (Goodman, 1978, p.6). Jakob von Uexküll[102] has taken a similar position, the basic insight in his work being that worlds are made of signs which have meaning for a subject (Brentari, 2013; von Uexküll, 1934). In these views, language systems facilitate the construction of worlds, by producing various descriptions of reality. A key point shared by Uexküll and Goodman is that all worlds are *world versions*[103] which, according to Goodman, can be regarded as worlds in themselves: "…for many purposes, right-world descriptions and world-depictions and world-perceptions, the ways-the-world-is, or just versions, can be treated as our worlds" (Goodman, 1978, p.4). Finally, such versions are always tied to a given perspective or "frame of reference":

> *"if I ask you about the world, you can offer to tell me how it is under one or more frames of reference; but if I insist that you tell me how it is apart from all frames, what can you say? We are confined to ways of describing whatever is described" (Goodman, 1978, p.3).*

In this perspective, worldmaking can be seen as a discursive act of combining symbolic components into wholes under a given frame. Thus, in considering worlds in general, and specifically design worlds, the issue of framing requires careful consideration. Schön has discussed the notion of framing in various works, explaining that the awareness of one's frame (via reflection) is critical for performing professionally (Schön, 1984), and that both "rules" and "types" (as he construed them) help in framing design situations (Schön, 1988). However, his accounts of design worlds and framing remain somewhat disparate, and the link between them is unclear.

We wish to bring these two strands together, by introducing a design world in which design representations are conceptually framed through narrative. Referred to as "narrative worlds", these aid in viewing design worlds as organized wholes, via visualization of the links between elements and their interpretations. In this, they shed light on the designer's perspective of the situation, and the way it is framed in real time. This endeavor demands the introduction of several conceptual tools for modeling both design processes and the discourse they entail, as discussed hereafter.

7.2.3 Taking the Designer's Perspective

In-line with Schön's approach presented above, which draws on the situated approach to cognition (Clancey, 1997; Clark, 1998; R. A. Wilson & Clark, 2009), Gero and Kannengiesser

[102] A brilliant biologist and cyberneticist who has dealt extensively with the notion of worlds, which he called "Umwelt".
[103] This is Goodman's phrase; occasionally appearing simply as "versions".

have formulated the situated function-behavior-function structure framework (situated FBS) (Gero & Kannengiesser, 2004).[104] Since it acknowledges the interpretive aspect of designing, we find this framework useful for this study.

Given its general nature, however, the framework cannot fully account for narration-in-action. The transformations in situated FBS occur between sets of abstract entities[105], independently of the values assigned to them in practice. In a broader sense, current tools and methods for modeling design processes tend to emphasize the form of the process over its contents. Some of our most detailed analyses of design cognition[106], or recent approaches for mapping design events and connections between them[107], take a similar approach. Since narration-in-action contains a strong discursive component, we need to equip ourselves with means for attending this dimension of designing. We thus complement the above tools with concepts from discourse analysis and the philosophy of mind, as explained hereafter.

The first concept which we arm ourselves with is that of "intentionality", viewed as a fundamental characteristic of the human mind (Crane, 2003; Searle, 1983). Not to be confused with "intention" as purpose, "intentionality" refers the fact that our thoughts are always thoughts *of something*, or *about something*. Further, the mind is said to engage in "intentional states", such that these states have both a type and content (Searle, 2004). As a simple example for an intentional state, imagine that you see a car and wish to buy it. In this case, you are engaging in an intentional state of desire (type) which is directed at this specific car (content). This study focuses on the manner in which interpretation is driven by the contents of the designer's intentional states.

For organizing this mental content, reflecting the designer's perspective of the situation, we rely on Fauconnier's mental space theory (Fauconnier, 1994). Mental spaces are virtual environments which speakers create by using "space builder" phrases, which establish contexts for conversation. By uttering the phrase "yesterday at the mall" we can build a mental space for hosting additional details, that may appear in the following conversation. For example, we can say that "John lost his wallet", which will add both John and his wallet to the space. In this sense, mental spaces can be thought of as abstract containers for entities introduced in discourse. Mental spaces enable to visualize the interrelations between these entities, by organizing them into larger wholes. In this chapter, these mainly consist of the design elements, their groupings and their interpretations. Thus, since we are interested in

[104] Refer back to 2.2.3.
[105] Namely - functions, behaviors and structures.
[106] For example, in architectural design by (Akin, 1989).
[107] Such as Linkography in (Goldschmidt, 2014).

how designers change their view of the design situation via framing and re-framing, we can use mental spaces to track the negotiation of these different perspectives.

7.3 Method and Task

7.3.1 Approach

In contrast to the design task presented in the previous chapter, which consisted of individual sessions, here designers worked in pairs. Working as a team enabled to elicit (and thus record) key-utterances in a rather natural manner, since the subjects had to communicate by speech when negotiating the task. Communication in design teams has been explored from various perspectives, and at different resolutions. For example, Stempfle and Badke-Schaub have studied patterns of regularity in team-communication, during a single-day design task. Their sentence-by-sentence analysis included both a "macroperspective" and a "microperspective"[108], and relied on classification of communicative acts (Stempfle & Badke-Schaub, 2002). Christensen and Ball have examined data from a five-day task to determine how analogy-based design is affected by design background (Christensen & Ball, 2016). In their case, design protocols were segmented and coded using the method proposed by Dunbar (1995). In another study, Song et al. have examined how interdisciplinary teams of design students engaged in storytelling, by subjecting oral and written documentation to a computational analysis of text coherence (Song, Dong, & Agogino, 2003).[109]

In line with the above, this work heavily relies on analyzing protocols, via segmentation and classification of key communicative events. However, keeping in mind our aim of modeling the designer's perspective of the situation at critical moments of interpretation[110], a key methodological difference with these is the level of analysis. Drawing on the terminology in (Stempfle & Badke-Schaub, 2002), this chapter takes a "nanoperspective", and examines how the narrative shapes the designer's perspective of the situation at specific moments in time. Design sessions are thus best seen as sources for extracting interpretation-related events, rather than complete accounts of how design problems are solved from start to finish. Moreover, we often draw our conclusions by comparing utterances with visual data (such as bodily gestures like pointing etc.), as means for verification (Murphy, Ivarsson, & Lymer, 2012; Sweetser, 2007).

[108] Focusing on occurrence of events along the design process vs. transitions between these, accordingly.
[109] Evidently, this is one of the few inquiries into storytelling in design teams in current research.
[110] For example, when framing or reframing occur.

7.3.2 Task, Environment and Setup

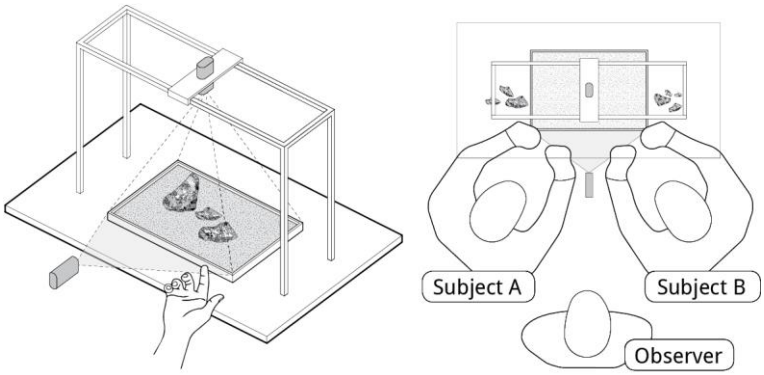

Figure 7-1 Task environment and setup.

We have repeated our task of designing a miniature JRG[111], this time with couples of designers who worked as teams (Fig. 7-1). Sessions were generally capped at 60 minutes, to constrain the complexity involved in interpretation.[112] While some teams chose to divide their time into several short sessions and produce several different design alternatives, others utilized it as a single, long session.

7.3.3 Participant Selection

All participants hold a bachelor's degree in a visual design discipline (Architecture, Industrial Design etc.) at minimum, with some holding a Master's as well. Participants were selected by their design background and work experience, from two groups: novice designers (less than 2 years of practical experience) and professional designers (more than 5 years of practical experience); under the assumption that this will enable to observe interpretation at different degrees of complexity. To facilitate communication, invited subjects were asked in advance to find a partner of an equivalent skill-level, that he/she would like to collaborate with.

Six couples (12 individuals) were observed in total. Two sessions were chosen as case studies, and are presented in this chapter. While in all cases interpretation was employed, to some extent, the chosen sessions demonstrate the interactive nature of design, namely how designers strive to conceptually frame the design internally, while considering and being affected by external reality.

[111] Here we mainly elaborate on the differences with the previous task; refer back to 6.4 for further details about the setup etc.
[112] And extended up to 90 minutes, when the subjects asked to continue, in order to complete their design.

7.3.4 Data Processing

Each design session was fully transcribed from the audio recordings. Our transcriptions included both literal utterances (both by the subjects and the observer) and descriptive comments (written by the observer during the activity) regarding the subjects' activity, e.g. bodily action, apparent emotional state etc., in order to establish a rich documentation of the session.

Still images, which are representative of design states, were then extracted from the video data. Each physical design move is generally represented by a single image. While the term "design move" was originally defined by Goldschmidt as an operation on knowledge (Goldschmidt, 2014), here we further specified it as a physical operation, thus equating a move with a physical shift in the spatial configuration of the structure.

Finally, the audio-visual data was synthesized into a single text-image sequence, which we refer to as a "design strip". A design strip serves a unified documentation of the design session, which displays the development of the structure along the design process, as well as the accompanying utterances reflecting the co-development of its interpretation.

7.3.5 Data Analysis

Processed data is then analyzed to track the usage of narratives as interpretive devices, for inquiring into the designer's perspective of the situation. We have followed these steps:

(1) **segmentation**: design strips were reviewed and divided into several meaningful sequences of moves, which we refer to as "design sequences". This is done via protocol analysis, by focusing on the current goals and persisting domains of discourse which are reflected in it[113]. Each design sequence is composed of a series of design moves. Design sequences are not uniform and may vary in length, intensity, and more.

(2) **identification of interpretation related-events:** these may be explicit (pointing at a rock and saying: "this is a mountain") or implicit (declaring that the sand is "a pool of water", which enables to infer that the rocks on it represent objects found in water); in accordance with the research aim and scope, we specifically, focused on the manner in which ambiguous arrangements of physical elements were attributed with interpretations, by letting them stand for another object.

(3) **focusing on key-phenomena:** by reviewing the textual narratives, points in the session where surprising events occurred ("focused event"), were identified. Focusing on these, we

[113] This can be thought of the "aboutness" of the sequence, i.e. what the discourse revolves around.

examined the changes in the designer's perspective before and after the event, by relating the structure, the gestalt imposed on it, and its metaphorical interpretation.

(4) **textual narrative production:** as a basis for placing focused events in a larger context, we have written verbal descriptions, as a summary of the design process, referred to as a "textual narrative". The textual narrative attempts to narrate the course of events, explicit intentions and observed actions from a high-level perspective, as a means for understanding the process as a whole. These narratives should not be seen as an analysis par excellence, but rather as a medium for providing an impartial yet non-fragmentary description of the session. Accordingly, they are written in an objective tone by relying strictly on actual events and utterances, while striving to minimize interpretive distortion.[114] Each part of the written narrative is supported by quoting utterances of the subjects in the body of the text.

(5) **organization and visualization:** the textual narratives and the design strips are used to further inquire into the entities involved in the focused event, as representative of the designer's perspective at the relevant time. Using these, state diagrams[115] were constructed, as a series of "pictures" of the design. Note that, in this chapter, we have sophisticated our state diagrams by integrating the notion of mental spaces (Fauconnier, 1994), as a means to trace the structure of the discourse. We then use these to try and understand the focused event from the subject's perspective, in the context of both preceding and following activity, by relating changes in the physical structure with changes in its interpretation.

7.4 Designing a Garden

We provide detailed accounts of events from two design sessions, which demonstrate how designers engage in narration-in-action, accompanied by figures representing key-episodes from the session. Figures contain numbered sequences of utterances (left column) and corresponding images of the structure at this time (right column). When an important utterance seems ambiguous, we have marked the verbal expression in a bold font, and the corresponding part in the image in a white line. Occasionally, figures are accompanied by a graphical explanation, which provides a visual summary of certain important aspects. Readers will find these helpful as complementary to the description of events in the text.

[114] Which may be caused by drawing inferences where clear information is unavailable, mis-attributing intentions etc.
[115] The reader can refer back to 6.4.3, where these were originally introduced.

7.4.1 Case 1: The Emergence of a Design World[116]

Harry and Neal are both novice architects who hold a Master's degree. Harry, has interned in architectural offices both in Germany and in Japan (two years in total), while Neal has interned for one year in a Japanese architectural firm.

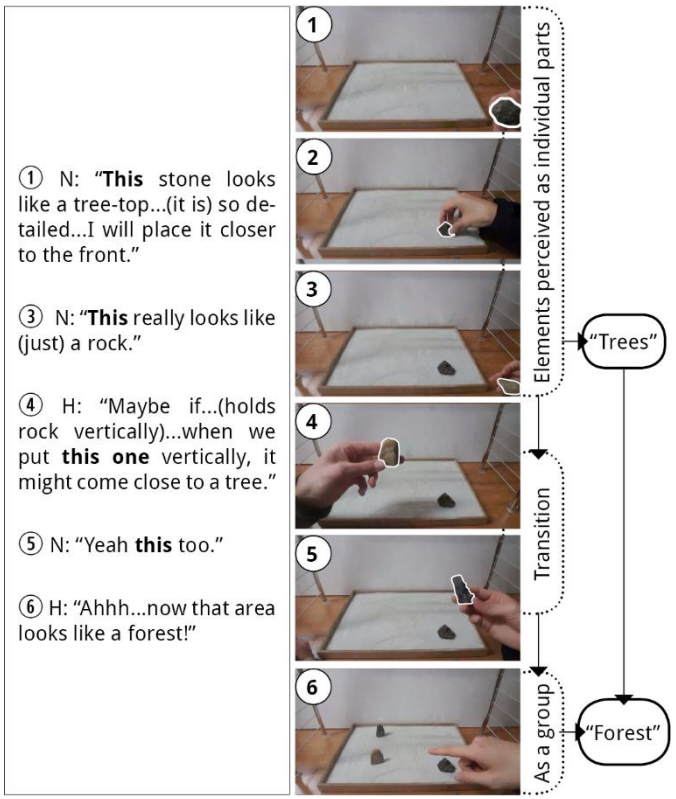

Figure 7-2 From object focus to area focus. Loosely defining the space which holds the newly created world.

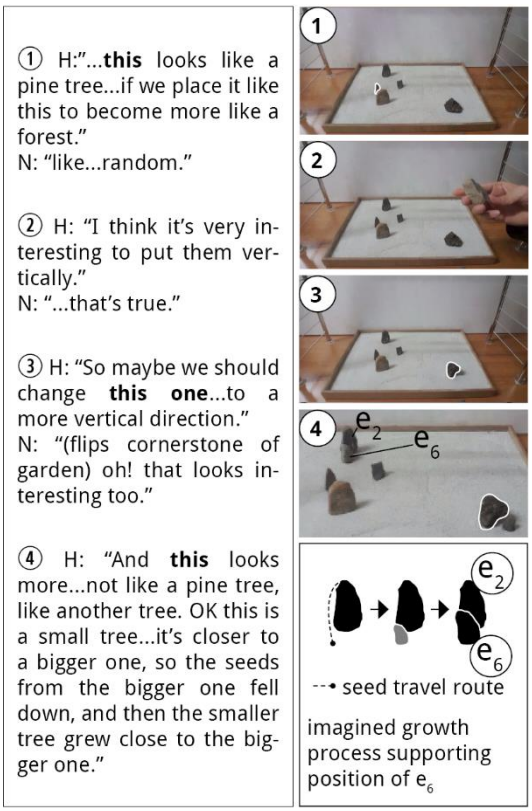

Figure 7-3 Endowing the world with the dimension of time.

Their session starts with a general discussion of the theme. Neal wishes to avoid traditional JRGs, which he is personally less fond of. Preferring gardens which contain more greenery ("natural garden"), he reaches for "something which reminds me...(of a) green thing", and grabs a rock which he could see as a tree-top. By placing this "tree-rock" in the garden space, he concretizes the foundation for their design. This is followed by a brief failed-attempt of seeing-as ("this really looks like (just) a rock"), to which Harry responds by proposing to reorient it to stand vertically, which would enable to see it as another tree. This prompts the immediate identification of a third rock which can fulfill the same role by Neal ("this too"). Having determined a first interpretation, and projected it onto several elements, a world is about to emerge. Harry proposes to progress by placing "them" randomly, i.e. he does not

[116] The full transcript for this session is given under A.4.3 in the Appendix.

refer to a specific rock, but rather to the number of “tree-rocks” they have found. When three rock are positioned in the garden space, Neal suddenly blurts out in surprise - "that area looks like a forest" (Fig. 7-2).

The interpretation of a "forest" is followed by a series of adjustments, during which Harry concludes that "it is very interesting to put them vertically". Accordingly, he changes the orientation of the cornerstone of the garden, to match the orientation of the other elements. Examining two “tree-rocks”, Harry further notices a height difference between them, which he interprets as a being a "small tree" and a "bigger tree". He does not seem content with simply acknowledging these differences, but goes on to explain their existence - "it’s close to a bigger one, so the seeds from the bigger one fell down, and then the smaller tree grew close". The world is endowed with a dimension of time, and its elements are further linked on the interpretive level (Fig. 7-3).

In a further attempt to tie the different elements together, a more detailed unifying interpretation emerges. Ingeniously, Harry proposes that a bird carried the seeds of a tree from one place to the other, which explains the spatial disparity of the tree groupings (more in 7.5.2, Fig. 7-11). Following this, the subject then reports - "for some reason right now, I suddenly see...a path here or a street". This observation, which seem to have resulted from focusing on the groupings and negative space, serves to encourage further elaboration of the design world, by segmenting the space into meaningful units or subspaces (tree groups, paths etc.).

7.4.2 Case 2: Emerging Narratives as a Way of Reasoning[117]

Nina and Dean are professional architects who have been running a joint practice for almost ten years, during which they have worked closely and intensively (“24 hours…365 days”). From the outset, their approach exemplifies the well-known tendency of designers for pushing the boundaries of the task. Dean opens the session with a spontaneous desire for “burying rocks”, explaining to Nina that he simply wonders “how good it (would) look” if they had “mounds instead of rocks”.

While he buries the first rock in one corner, Nina concludes that the interaction between the rocks and the sand seems key for designing in this task. They continue by adding another rock at the opposite corner from the first one, agreeing that it should be “showing a little bit”. When examining the available rocks, the two mention (almost in unison) that they usually prefer doing “several trials”. This is followed by a shared decision to use the current design as a “first trial”, which Nina characterizes as focusing on how rocks are “placed in the sand” (Fig. 7-4).

[117] The full transcript for this session is given under A.4.6 in the Appendix.

Nina then points-out the existence of "two types" of rocks in the current composition - buried vs. partially-buried. The two agree that one rock should be "totally buried" and another "just standing". In what may be described as a visual interpolation on the diagonal axis of the tray, they decide to "make a gradation of exposed and buried" rocks, further elaborating the current theme. Since the rock placed in the back-right corner is slightly buried, Nina resolves to add another one between it and the corner of the tray, to serve as the last element in the sequence (i.e. a completely exposed one). Three more rocks are added to complete the axial gradation, resulting in a six-rock sequence along the diagonal (Fig. 7-5).

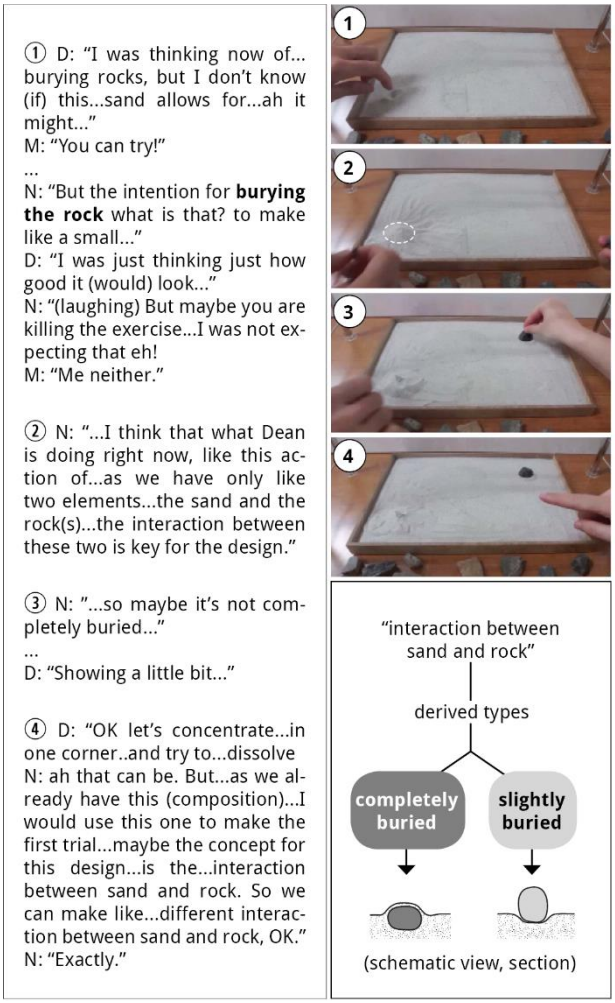

Figure 7-4 Setting the stage.

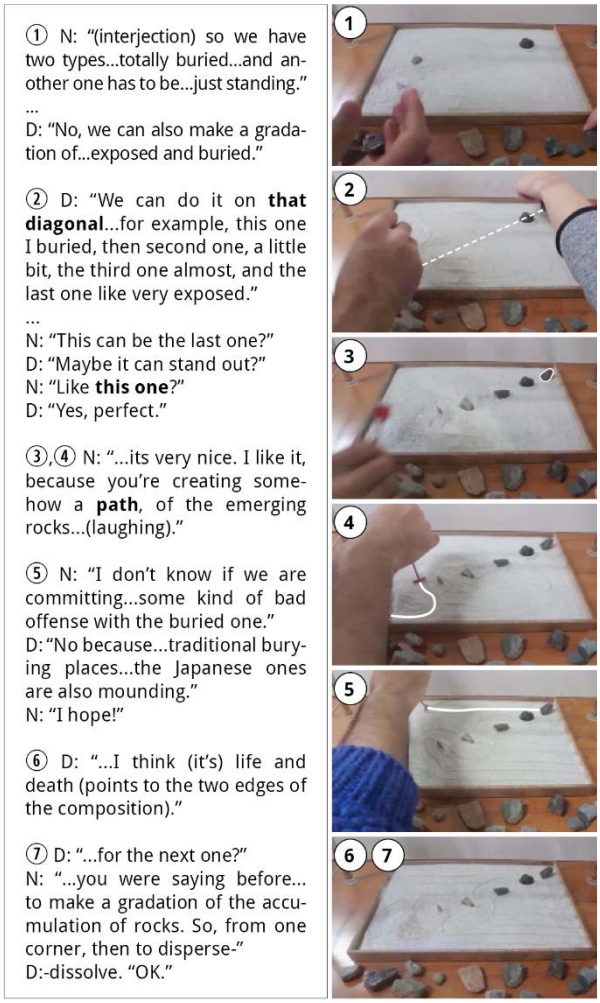

Figure 7-5 Elaborating the first concept.

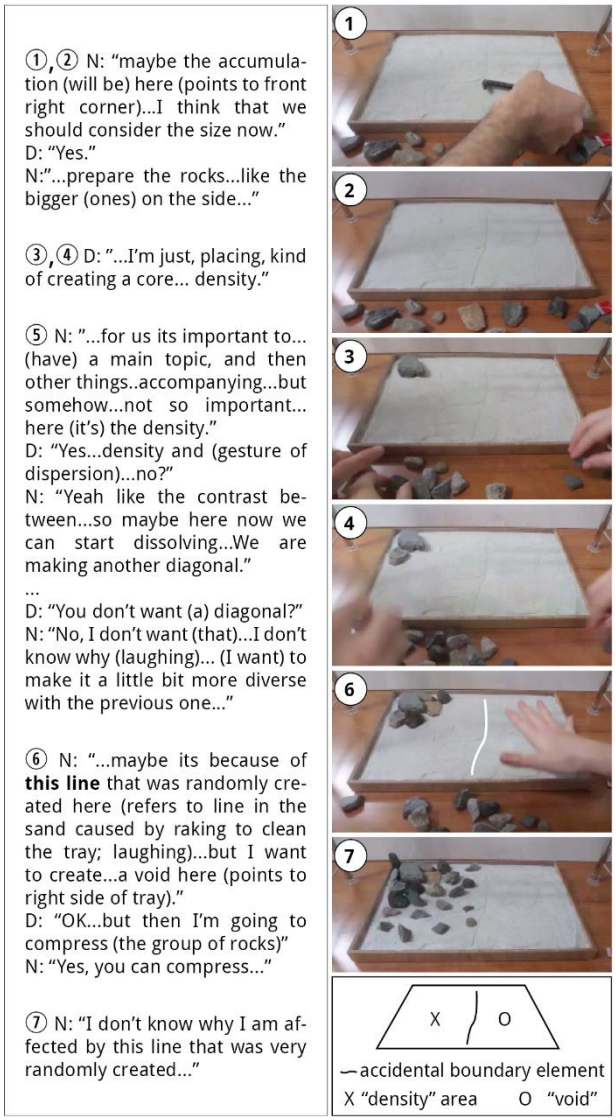

Figure 7-6 Spontaneous adoption of elements.

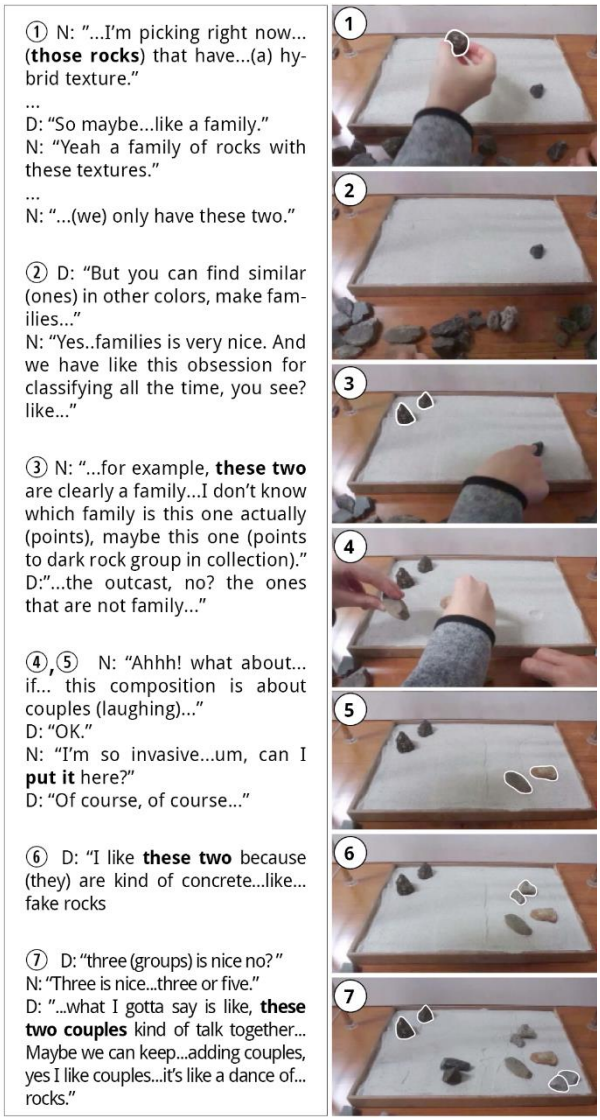

Figure 7-7 Emergence of couples.

Dean completes the design by raking the sand in two stages. First, he creates a winding trail along the diagonal (which Nina humorously characterizes as "the path of the emerging rocks"), as if to weave the different rocks together. Then, he rakes the sand in the unused space to create a pattern of horizontal lines, in parallel with the longer edge of the tray, to clear the messy parts caused by the creation of mounds, which Nina did not like. Nina half-jokingly wonders if they are "committing...a bad offense" by burying the rocks, and seems to enjoy stretching the boundaries of the exercise. Dean mentions that mounds are commonly found in traditional Japanese burying places, and concludes that that the two extremes of the diagonal can be seen as "life and death" (Fig. 7-5 bottom, enlarged in Fig. 7-8).

In their second trial, they return to Dean's previous idea to go “from one corner…(and) disperse” (mentioned in Fig.7-5). Nina observes that they are “making another diagonal”, which she finds undesirable, since she would like to “make it a little bit more diverse” (with respect to the previous trial). While attempting to redefine the spatial layout, she notices an accidental line in the sand, caused by the raking action that had previously taken place, when clearing the space. She finds this line suitable as a boundary for the dispersion of the rocks, and decides to “create a ...void here” (i.e. to exclude rock placement on the right). Dean then “compresses” the rocks to the corner, perhaps to leave enough room for dispersing without crossing the boundary line. Later during the session, Nina reflects on this matter of using the line as a boundary element, wondering: “why am I affected by this line that was so randomly created?” (Fig. 7-6).

The third and last trial opens with the observer’s suggestion to work separately on two different compositions simultaneously and then try merging them, to which the subjects gladly agree. While trying to set the “rules” for this trial, Dean jumps in and decisively places a rock in the space. Nina responds by deciding to focus on “color” in this design, and picks up a rock which has a “hybrid texture”, stating that she is “going to select these ones”. Dean replies that these rocks (with the hybrid texture) are “like a family”, an interpretation which Nina accepts (Fig. 7-7, 1).

Nina says she does not want to use other rocks (outside this family), yet notices that only two such rocks are available, with mild disappointment. Dean proposes to resolve this by finding “similar (rocks) in other colors, make families”, and Nina suddenly exclaims in surprise - “ooh, we are already collaborating!”. Accepting Dean’s idea, she says that “families (are) very nice”, and they start grouping the available rocks into “families”, roughly by color/texture. Nina adds that they “have an obsession for classifying”. Dean explains that this helps them deal with the lack of constraints, since they are “used to working in context”, which sets a lot of limitations that structure the activity. He thinks that it’s good to “set the borders” and then “play within” them.

Taking two rocks that are “clearly a family” (the rocks with the “hybrid texture” from the beginning), Nina places them on her side of the tray. After a brief discussion, Nina suddenly points to the lone cornerstone rock and says - “I don’t know which family is this one actually”. Dean responds by proposing to create a family of “outcasts”, thus expanding the notion of a family to include similarity on a higher-level, in relation to the other rocks (Fig. 7-7, 3).

Nina points out that currently the smallest family consists of two rocks. She then grabs two rocks (forming a family), one in each hand, and tries to place them in the space, when she suddenly exclaims in discovery: “Ah! what about...if... this composition is about couples?”. Dean agrees, and after some discussion, picks another “couple” (which he likes because they

"are kind of concrete" and look like "fake rocks") and places them in the garden. A bit later, Dean points to the rocks in the front-right and back-left, refers to them as couples, and says that they "kind of talk together", a point at which it seems that the concept of "families" has completely transformed into that of "couples". He thus proposes to "keep...adding couples" and says that he "like(s) couples". Finally, he characterizes the design as a "dance of rocks". (Fig. 7-7, 7).

7.5 Narrative Worlds

We propose to see interpretation as an activity driven by the generation of interpretive worlds, referred to as "narrative worlds". Their description sheds some light on the manners in which designers view and navigate design situations, when working with design representations. As an initial example, see Figure 7-8 below. Here, rocks were placed by the designers in a diagonal sequence, as to gradually emerge from the sand, from completely buried and up to fully exposed. This composition was interpreted by the designers as "life and death", thus attributing each end-point of the sequence with an interpretation, while positioning all elements within a shared conceptual framework.

Figure 7-8 A narrative world: "Life and death" or "the path of the emerging rocks"; case 2.

Let us step into these worlds in two stages. First, by introducing a simplified version of a narrative world formed in case 1. Second, by identifying several phenomena concerning their inception and elaboration, demonstrated using the data from our design task.

7.5.1 A Picture of a Narrative World

Narratives formed when designing assign elements with conceptual descriptions as interpretations. Such descriptions both reflect and affect how the designer sees the structure, while changes made to the structure may cause changes in the description as well. In this sense, narratives in design are distributed over the physical and the mental. When designers engage in narration-in-action, they are in fact attempting to organize both the structure *and* their interpretation of it, simultaneously. Considering that narratives are tools for sensemaking and synthesis, this activity is expected to converge into a coherent result, i.e.

into a satisfactory structure and a "good" narrative.[118] This convergence necessitates maintaining certain links between physical elements and their interpretation, over the course of the activity.[119] The narrative world aids in modeling the manners in which these links are formed at specific moments in time, when trying to harness the narrative to bridge external and internal reality.

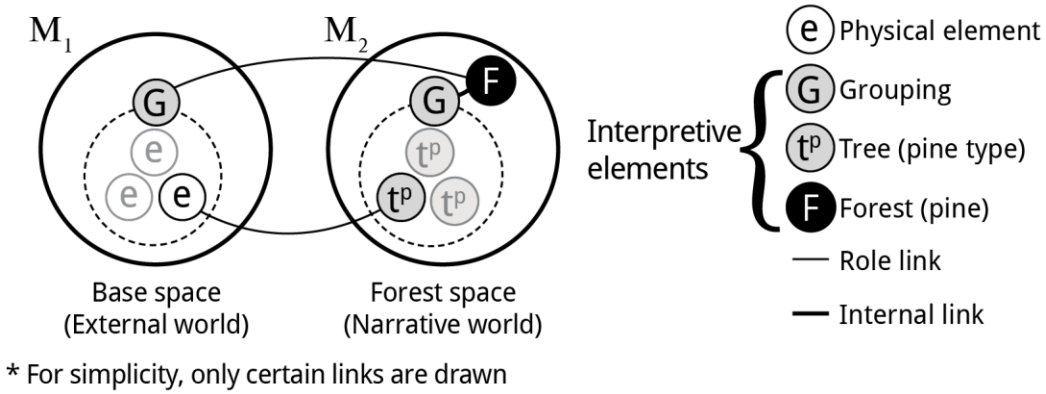

Figure 7-9 Visualizing the designer's perspective using narrative worlds.

Figure 7-9 provides a simplified example of modeling the designer's perspective, using the notion of narrative worlds and mental space theory (Fauconnier, 1994). Two mental spaces are drawn: M_1 (external reality) and M_2 (the narrative world); these are contained in the external and interpreted worlds of the situated FBS framework, accordingly (Gero & Kannengiesser, 2004). Recalling the event in case 1, where the designers have seen the space as a "forest", we model it as follows: since the external world contained several rocks prior to the appearance of the "forest", we placed three elements in M_1 which represent these (each corresponding with a single rock in the physical space). As each rock was interpreted as a "tree", we connected each element in M_1 with its interpretive counterpart in M_2 (each representing a single tree in the designer's imagination). Further, since the trees were finally seen as a forest, they are grouped within the narrative world, and linked to a forest element. Finally, the fact that the designer had "seen" the forest implies a gestalt grouping of the physical elements, noted by grouping the elements in M_1, as well as by linking this group to the forest in M_2.

[118] As explained by Bruner, the narrative mode of thinking aims at "good narratives" (Bruner, 1986); here we may think of these as either those which fit the designers' view of the structure, enable to gain certain insight into new design solutions, or simply ones that are readily accepted by the designer, based on other criteria.
[119] For a discussion of synthesis and convergence, see (Alexander, 1964).

The link between an element and its interpretation was named as a "role link", since the interpretation determines the role that the element metaphorically plays in the larger narrative. These links thus connect physical elements with their imaginary counterparts.

Establishing roles links is generally done by metaphorically naming an element ("this is a tree"). From a narratological perspective, such utterances may be seen as verbal stasis statements of the narrative discourse, introducing new existents into the story (Chatman, 1975). Therefore, role links are not merely referential, but generative as well - the "tree" did not exist as an entity in the narrative world before the rock was assigned with this role. Furthermore, establishing such links shapes the designer's perception of the original object and its contextual space.

Finally, a clarification is due with respect to the entities populating these spaces. Two types of elements are presented in Figure 7-9: physical (white) and interpretive (gray/black). Interpretive elements are associated with specific types, noted in parentheses. For example, "tree" is associated with "pine tree" or simply "pine". What is visualized in the narrative world are not types, but rather type-instances. However, any interpretive element can potentially be later taken as type, since the designer can draw upon it as a source of knowledge for interpreting additional elements.

7.5.2 Generative Factors

This sub-section discusses the circumstances under which narrative worlds form and evolve, during narration-in-action. As shown in 7.5.1, establishing role links populates the narrative world with entities. This, however, does not tell us how the narrative world is structured as a whole. Suwa and Tversky have suggested that shifts in focus are important drivers for design (Suwa & Tversky, 1997). Indeed, we find that the formation of narrative worlds as wholes is associated with shifts in levels of observation, in terms of groupings. Continuing with case 1, after an initial interpretation was assigned ("tree") by focusing on a single rock ("this looks like a tree-top"), the subjects resolved to freely place several rocks in the space. This was immediately followed with seeing the design as a "forest" (Fig. 7-2). The emergence of this forest, which served as the global interpretation (or setting) of the design, may be described as follows: first, an interpretation was assigned to an individual element. Then, several elements were placed in the space, inheriting this interpretation, and consequently perceived as a group. [120] Finally, a unifying interpretation was proposed. The forest setting was thus generated as a consequence of re-perceiving the physical elements in under a different gestalt, which demanded adapting the interpretation by relating the parts (trees) with a new whole (forest). Similar events were observed in other sessions as well.

[120] Of course, additional factors may be involved here; for example, the similarity between the elements etc.

Figures 7-4, 7-5 demonstrate how the professional designers go through a similar process in several phases. First a single type is created (buried rock). Second, an element is added in a manner which leads to the implicit creation of a second type (exposed rock). Third, the existence of two types is explicitly acknowledged ("we have two types"). Finally, the subjects decide to "visually interpolate" the two rocks, forming a diagonal gradation in surface exposure. Here, the designers opened with an element-level observation, moved to a transitory phase of recognizing the existence of different types as components of a larger potential grouping and, finally, unified these into a group via a strategy which placed the existing elements and their interpretations as end-points on a larger sequence. For clarification, we speak here of the initially placed rocks as types (rather than simply type-instances) since the designers have clearly drawn on them as prototypical sources of knowledge in producing their design.

Rather than strictly bounded or well-defined, narrative worlds seem fluid and open for further structuring. In our design task, this is highly prominent in the case of the professional designers, which are prone to welcoming unintended elements into their world. Figure 7-6, for example, demonstrates how the subjects serendipitously structure their narrative world, as a response to an accidental line on the sand - the line is embraced and interpreted as a "boundary" between two areas of full and void, thus serving as a dividing line for the setting, which otherwise remains largely undefined.

Case 1 provides us with an additional interesting example for such flexibility. Here, the designers resolved to expand the interpretive framework by detaching from the physical dimension, and introducing existents into the story which do not have any external representation (tree-seeds and birds). This helped in enriching the narrative[121], but more importantly, in strengthening its integrity. The placement of elements in the space was further justified by a chain of causation, in which both the physical and the purely mental played a part.

Finally, a certain type of conflict (between types and rules) seems to play a central role in structuring the narrative world, continuously motivating designers, to coordinate their perceptions and interpretations. More specifically, when the expectation of designers from elements as type-instances conflicted with self-generated rules, the designers' interpretive faculties were triggered into action.

[121] Which is interesting in itself from a perspective of creativity in design.

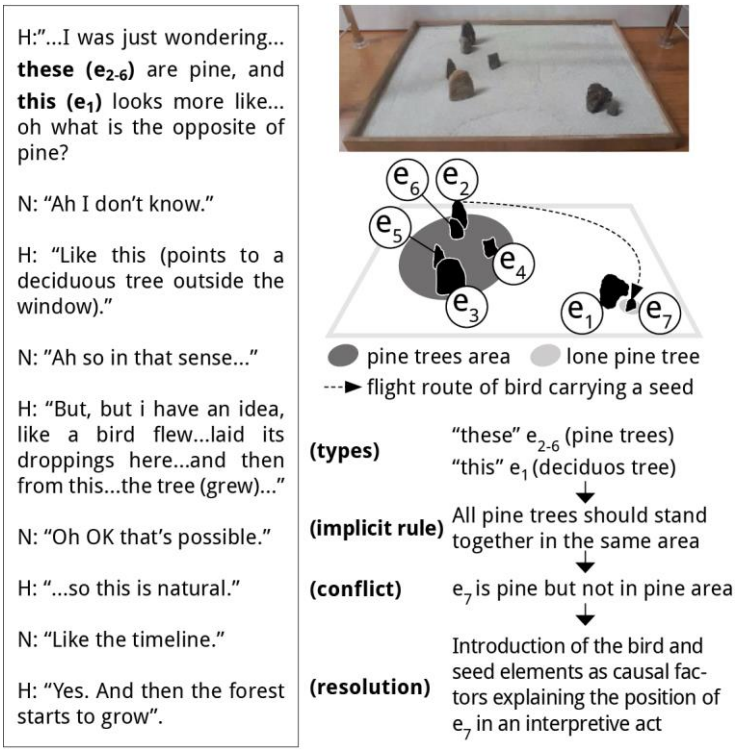

Figure 7-10 Creative negotiation of interpretations via narrative.

An intriguing example for this is evident in the above sample from case 1: the subjects were building a "forest", where each rock was interpreted as "tree". Further, two types of trees were identified: "pine" and "opposite of pine" (deciduous). One subject noticed that a rock characterized as "pine" stood physically far from its group, and wondered why this is so (i.e. how could it be that it "grew" out of the "pine area"). To resolve this, two new elements were added to the interpretation - a *bird* which carried a *pine seed* from across the forest (Fig. 7-10).

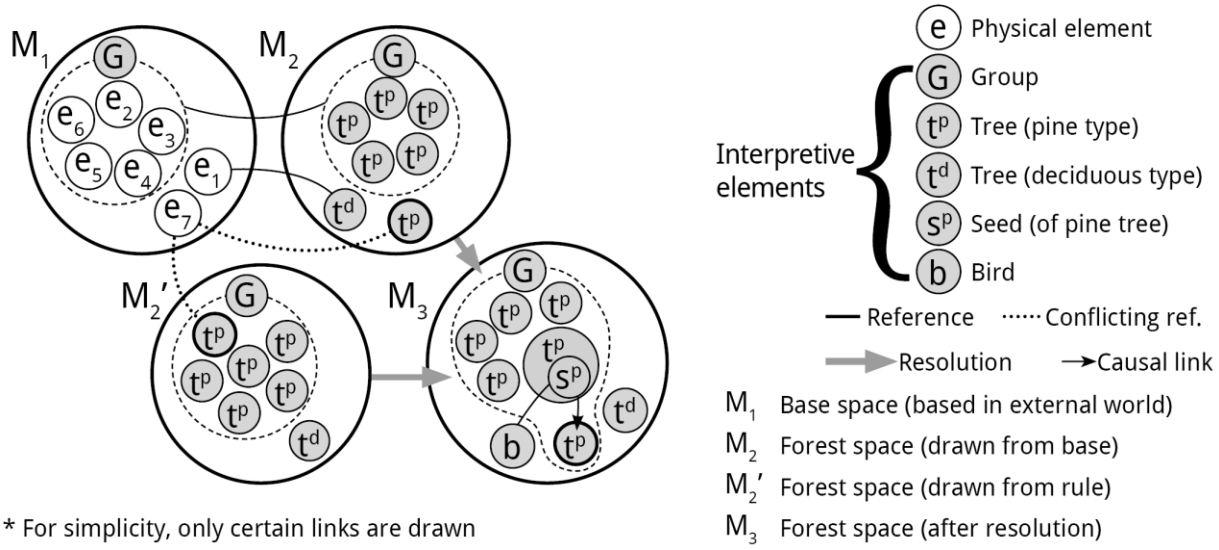

Figure 7-11 Visualization of negotiating different views via our approach, following (Fauconnier, 1994).

The above extract can be understood as a discrepancy between two mental spaces, as shown in Figure 7-11. M_1 represents the designers view of external reality at the initial state, where certain rocks were grouped (those in the "pine tree area") and others remained outside the group (e_1,e_7). M_2 and M_2' represent two possible narrative worlds, and M_4 is the narrative world which result from these. In M_2 the grouped rocks, as well as one rock outside the group (e_7), are all assigned with the interpretation of "pine trees". This space represents how the designer sees the situation on the interpretive level without considering the implicit rule "all pine tree should stand together". M_2' on the other hand, represents the understanding of the situation by considering the implicit rule. Accordingly, in this space, e_7 also appears withing the "pine tree" group, reflecting the designer's expectation of following the rule. The conflict stems from the fact that, while the designer expects all pine trees to stand together, he perceives a strong grouping which excludes one element (e_7). M_3 shows the designer's perspective after resolving the conflict – the fact that the implicit rule is broken is coped with creatively on the interpretive level, by forming the bird story, which enabled e_7 to both be out of the group on the perceptual level and in the group on the conceptual level.

Case 2 provides us with additional interesting occurrences of such negotiation and elaboration of the narrative. After establishing a general design strategy of "creating families" of rocks, the designers started to group rocks by similarity, as preparatory categorization. One subject then pointed at a rock and said that she cannot find a family for it. The other subject found it unsatisfactory to leave it uncategorized, and relieved this tension by proposing a new category, and thus a new type called "outcasts". Notice that this type was

not defined positively, but rather negatively in relation to another type (Fig. 7-7, 3). Further, notice that the later frame concerning "couples" emerged after the subjects resolved to "make families" but ran into difficulties, since in some cases the total number of "family members" found was only two. This was spontaneously resolved by the decision to make "couples".[122] Notice that this session provided us with another example for framing ("dancing couples") which lacks the specification of a clear setting (as in their other sessions), which may be explained by the professionals' capacity for "dancing with ambiguity" (Leifer & Steinert, 2011), as a means for maintaining flexibility in their design.

7.6 Discussion

In considering the basic nature of narrative worlds, the following description by Uexküll seems enlightening:

> *"If we now continue on our way, we shall enter worlds that feature very effective phenomena which, however, are visible to the subject alone…We shall call Umwelten of this kind magic worlds"(von Uexküll, 1934, p.67).*

Narrative worlds are private "magic worlds" which structures the subject's experience of design representations. As such, they provide us with rich information of the designer's view of the situation. How do they enable us to take the designer's perspective?

7.6.1 Implications

As explained in 7.2.2, Schön has provided us with a rich language for discussing the internal world of the designer. Our proposed modeling approach draws on his work, as well as other important conceptual tools, for making "pictures" of the designer's perspective at a given time. These pictures expose the way that the design situation is framed as multi-dimensional construct, based on certain intentional (mental) content. Multi-dimensionality refers to the fact that the both the external and narrative worlds contain elements of their own (physical vs. interpretive), each existing on its own plane and subject to certain groupings. In this view, narration-in-action can be seen as the coordination of two somewhat autonomous planes of perception and conception. This autonomy is made salient in extreme cases (as in Fig. 7-10) in which the narrative is first formed based on external reality, but then enriched in a purely imaginary manner. Such events make a strong case for considering design worlds as "worlds", exposing the narrative world as the designer's internal playground for changing their perspective of the situation.

[122] Interestingly, this may have emerged not only from the mental conflict, but also from the bodily posture, considering that the subject was holding one rock at each hand, when conceiving of it.

Considering more realistic design tasks, such as Goldschmidt's task of designing a residential unit based on the concept of a "cube" (Goldschmidt, 1988), we can now raise questions regarding interpretation from the designer's perspective: if a house is said to be a "cube house", what metaphorical roles do the different architectural elements play in expressing the designer's vision of a "cube"[123]? Such questions, which are of great importance for deepening our understanding of subjectivity in design, may be answered by modeling the relations between the architectural elements, their interpretations and their grouping, using our approach.

Furthermore, while the above comments were made on a content-level, our modeling approach proves as effective on a process-level as well. An important behavioral pattern is evident in the findings: the designers formulate a self-imposed rule (whether consciously or not), which is then somehow violated by the state of external reality. In cases where the designers are unaware of the rule, it is discovered when the conflict arises. As previously explained, awareness of the frame is necessary for performing professionally (Schön, 1984). This explains the role of such conflict as a way to elicit latent thoughts and bring them into awareness, to enable to consciously strive for coherence. More importantly, however, this means that awareness of the current frame cannot be complete without the awareness of our underlying rules which structure it.

In a broader sense, this work serves as a bridge between design theory, discourse analysis and the philosophy of mind. In an era where the study of design cognition is in true need of new tools and methods for moving forward (Hay, Cash, & McKilligan, 2020), and where new technology relies on insight from design cognition (Goel, Vattam, Wiltgen, & Helms, 2012), such interdisciplinary efforts to establish new ways for inquiring into the mental realm seem of great value.

7.6.2 Limitations and Future Work

Key limitations and possible future directions are discussed. First, our description of narrative worlds serves as an account of the designer's perspective, and enables us to derive information *about* the frame held at a certain moment. However, much work will be required to elaborate the notion of a "frame", and enable its explicit description. Considering Beckman and Barry's two-phase process of framing and re-framing (Beckman & Barry, 2009)[124], it seems that describing the components and boundaries of frames are essential for understanding design innovation processes. Doing so would require to move beyond the metaphorical interpretation and include additional layers, which contribute to it as a whole. As an example, consider the social aspect of the activity (e.g. the way designers see their

[123] Which can be seen as representative of the project's narrative or frame.
[124] Of capturing the process within an initial frame which is then improved upon.

personal role during the task) which surely shapes the current frame. This aspect could be hypothetically studied by harnessing additional tools from pragmatics (Levinson, 1983; Searle, 1969), for understanding the context in which the discourse is embedded.

Second, our task was designed to reduce the complexity involved in real design situations, and enable a deep analysis of narration in action. Our choice of JRGs has enabled to achieve this, at the cost of setting aside the important aspect of function. This aspect should be carefully integrated into further inquiries, while keeping in mind the need for providing sufficient opportunities to engage in interpretation. As a midway, we propose the possibility of designing miniature gardens which are associated with interpretative practices, but are not limited to viewing. For example – in Chinese traditional gardens one can sit, walk around, observe and even touch the decorative rocks (D. Zhang, 2018). To facilitate interpretation and framing, while enabling subjects to attend to technical aspects, we recommend that the task duration is significantly increased.

Finally, since designers are not only the senders but also the receivers of their own narratives, understanding this practice requires an account of both how the narrative is "written" (via speech) and how it is "read" (via hearing). These actions can be seen as the generation of the narrative discourse and what Bruner has referred to as the "virtual text"[125], accordingly (Bruner, 1986, p. 25). This study has focused mainly on the "writing" as opposed to "reading", which may require to employ additional methods, to expose the internal image which designers see according to their specific "reading" [126]. Recalling Krippendorff's "hermeneutic circle" of sensemaking (Krippendorff, 1989, p.13), it seems that the designer is caught in a double-loop - sensing and synthesizing the structure on one level, while being aware of changes in the interpretation on another level. The challenge of achieving a realistic account of narration-in-action thus may require us to adopt the lens of second-order cybernetics (Herr & Fischer, 2019; Scott, 2004), and it's tools for modeling self-observing systems.

7.7 Conclusion

A new approach for modeling the ways in which designers conceptually frame and understand interpretation activity was proposed, demonstrated and discussed. A key component of this approach is the notion of "narrative worlds" - interpretive worlds which enable to map and visualize important relations between external and internal reality in design. Tracing the emergence and transformation of these worlds aids in understanding how

[125] One's individual rendering of the narrative discourse in his/her imagination.
[126] A potential method would be sketching, as it enables subjects to express their thoughts freely, given a sufficient skill-level.

designers subjectively view the structure during interpretation activity, thus shedding light on how they reason about it, via interpretation.

In a broader sense, our modeling strategy is grounded both in empirical data and in existing knowledge of design cognition, discourse analysis and intentionality. As such, it serves as a bridge between several domains of thought, which seem essential for studying issues of subjectivity in design. Therefore, it lays an important foundation for drawing insights from design cognition, towards the enhancement of future computational design systems.

Chapter 8 Discussion

This chapter opens with a unified account of the main contributions of this work, which deepen our understanding of interpretation activity as a whole. Next, we discuss of the knowledge gap in current models for design which our work begins to fill. This is followed by a clarification of our achievement and of the originality of this work. Finally, we discuss the implications of our findings to design research and practice, and the main limitations of this work, as a basis for future research.

8.1 Contribution: General View of Interpretation of Structure

The core contribution of this work is the vocabulary and thought framework for understanding the activity of interpretation of structures. Our newly proposed notions introduced throughout the work, which contribute to this effort, can be unified by framing interpretation activity as an act of world making, in which designers produce interpretive worlds. We have referred to these worlds as "narrative worlds" (NWs).[127] In short, NWs are abstract constructs which relate physical entities and their interpretation in a structured manner. As such, they can be used for systematically inquiring into the agent's mental image of the physical structure, during interpretation activity.

Fig. 8-1 below places the notion of NWs within the larger context of current models for design agents. The figure aims to provide an intuitive understanding of how NWs extend our possibilities for computation within artificial design agents, by fluidly bridging external reality and internal (mental) reality. The bottom layer[128] refers to the world in which the agent is physically embedded, and that may be accessed by the agent via the layers above it. The structure is also found in this layer. Above these are three processes of sensation, perception and conception, continuously executed by the agent (Gero & Fujii, 2000).

Focusing on the conceptual layer, we first see that the designer conceives of the artifact by using natural language. Our ability to use natural language serves as the basis for constructing both the situated FBS worlds (Gero & Kannengiesser, 2004), and the NW itself. The NW is constructed in real-time by the agent, via interpreting the structure using verbal descriptions. Notice that we have positioned the NW above the situated FBS worlds. The reason for this is that, while worlds in situated FBS deal directly with descriptions of the

[127] As introduced in chapter 7.
[128] Regarding the notion of the "substantial world" see (Fujii, 2019).

structure itself[129], the NW rather deals with the mental image projected on the former (via metaphor) by the designer. We can understand the NW as the conceptual sphere in which some of the content from the situated FBS worlds is mentally organized as a coherent image of the structure.

This image contains some of the mental content designers hold internally, reflecting how they subjectively view the structure.[130] We believe that this content is highly valuable for understanding designers' subjective perspective, with respect to the designed artifact. Furthermore, as we have demonstrated in chapter 7, the mental image can be captured within symbolic descriptions, to a certain extent. Accordingly, it can be represented in formal language. This possibility is represented by drawing an arrow from the NW to the formal language component. Formal language, and specifically a future formalized model of NWs, leads to the derivation of knowledge via computation. Computation here refers to reasoning about interpretation of structures by manipulating symbolic descriptions. Finally, the derived knowledge serves as a basis for action.

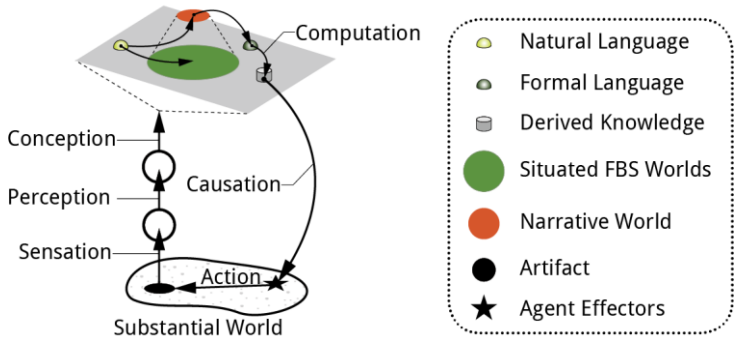

Figure 8-1 Placing the narrative world within current frameworks for artificial design agents.

Finally, in Figure 8-2 we schematically relate important notions that were introduced throughout the work, as well as several key-ideas from existing research on the topic, with the notion of NWs. This is done by placing them in four general categories, with respect to their contribution in forming NWs.

[129] Its functions and behaviors, and the manners in which these are interpreted etc.
[130] We expand on this in 8.4.

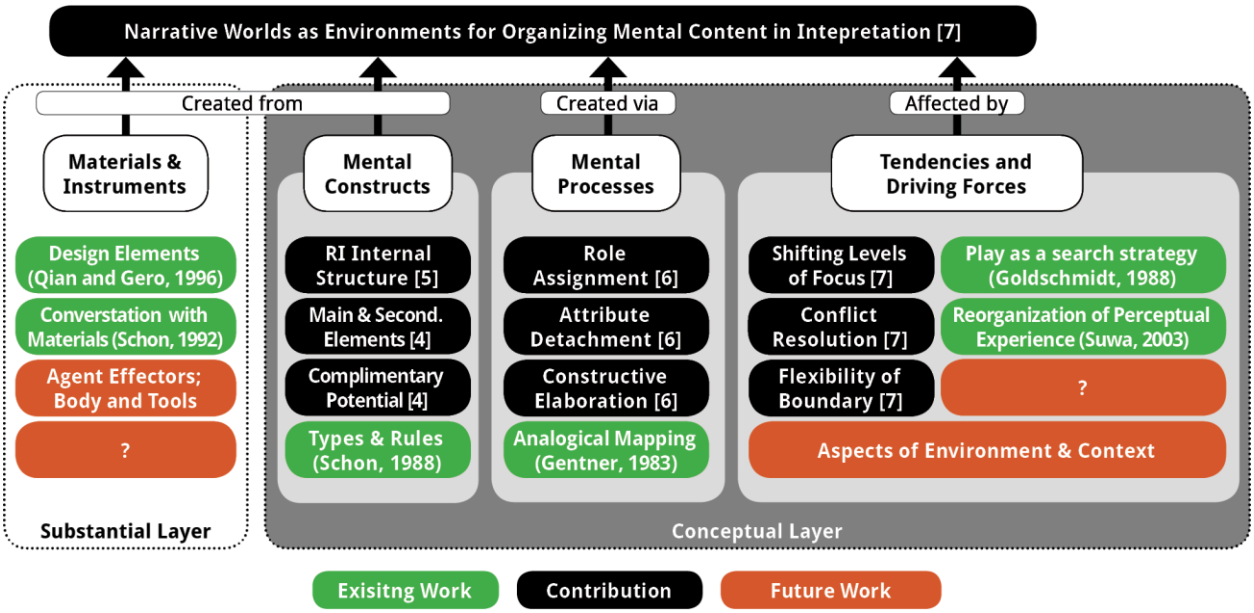

Figure 8-2 A general view of interpretation in conceptual design as an act of world making.[131]

Table 12 Summary of terms and notions introduced in this work.[132]

Type	Term	Explanation	Ch.	Importance
Mental Constructs in RI	Narrative world (NW)	The NW is a mental environment which is metaphorically imposed on the structure, and shapes the designer's conception of it. The basic entities composing the NW are design elements and roles. A NW is generally formed by assigning roles to more than one design element.	7	The NW both unifies the activity of interpretation of structure within a single-thought framework and ties it with the notion of Mental Spaces (Fauconnier, 1994), thus offering a practical way to model interpretation activity which is grounded in discourse analysis.
	RIs	During role assignment, concepts are associated with the structure, so that the structure stands for the referent of the concept (see below). RI refers to the symbolic logical construct which metaphorically relates a high-level concept with low-level spatial relations.	5	The internal structure of RIs, as formulated in our framework, is essential to account for the way in which agents internally justify matchings between the artifact and the concept. Without it, we cannot realistically represent interpretations withing a computational system, since the representation will lack grounding.

131 Notice that NWs encompass our various insights; separation into substantial and conceptual level according to (Fujii, 2019).
132 Complimentary to Figure 8-2.

Mental Processes in RI	Role assignment	Refers to the act of assigning a symbolic description to a design element, so that the design element stands for the referent specified in the symbolic description.[133]	6, 7	An action that agents take to form NWs. Assignment frames the agent's view of the design element, defines its potential within design activity and results in a mental projection of certain qualities onto the structure, driving interpretation and action.
	Constructive elaboration	Once a role has been assigned, the agent may assign additional roles to other elements to elaborate or enrich the original interpretation.	6	Demonstrates that the agent's actions not always arbitrary, but may depend on previous events. This points to the fact that reasoning is essential for accounting for interpretation in design.
	Detachment	Refers to a design strategy by which an attribute or role is transferred between design elements.	6	Provides an economical strategy for constructively adjusting the structure while maintaining the desirable aspects of its interpretation.
Tendencies & Driving Forces in RI	Shifting levels of Focus	Refers to the phenomena of switching between different gestalts; an important driver for design in general (Suwa & Tversky, 1997), and specifically for interpretation.	7	The formation of NWs has been observed following shifts in the level of focus, pointing to the potential importance of such shifts as generative events in interpretation activity.
	Conflict resolution	Refers to the natural tendency of the agent to negotiate conflicting views, which is evident as a causal factor which shapes interpretation activity.	7	Conflicts are basic drivers in RI, and important for the constructions of NWs. The actions of the agent can be understood in some cases, by examining conflicts preceding them.
	Flexibility of boundaries	Refers to the agent's openness in drawing the boundaries of the NW, by responding to unexpected happenings during the design process.[134]	7	Such flexibility is critical for modeling the regulation of potential changes in the NW, as a result of interaction with the environment; strongly correlated with the important phenomenon of reflection-in-action (see Schön, 1984).
	Main & secondary elements	A main element is an element which the agent would like to maintain as a part of the structure independently of other elements. Secondary elements depend on main ones.	4	This distinction serves as a fundamental property of the agent's perception and experience of the structure. The implementation of interpretation in an artificial agent would necessitate a capacity for making this distinction.
	Complementary potential	Refers to the ability of an element to shape the interpretation of another in the structure. Finds its roots in the concept of Affordance (Gibson, 2014; Maier & Fadel, 2009).	4	Important for understanding the dependency which existing between design elements during interpretation activity, which is partially derived from their spatial relations. Proposes a criterion for filtering and selecting design elements during interpretation activity by artificial agents.

We believe that the notion of NWs serves as an important missing link in current attempts to model design from a computational perspective. This claim is laid out and supported in the next section. Finally, Table 12 above provides a summary of terms and notions introduced in this work, and their importance in deepening our understanding of interpretation of structure, with respect to their contribution to the idea of NWs as interpretive mental constructs.

8.2 Considering the Designer's Perspective in Computational Models for Design

In the previous section, we have described NWs as a device for organizing the relations between the structure and its interpretation, enabling us to inquire into the agent's mental image of the structure. We have further claimed that it fills a knowledge-gap in our current ability to model design activity. This sub-section describes this gap, and the way it is bridged by the notion of NWs. We do this by placing the work within the prevailing approaches for design computing.

How do we begin to model design for its implementation in computational design systems? Such a discussion would do well to open with the important work done by Christopher Alexander. With the aim of establishing a model for design processes from a computational perspective, Alexander has proposed to model design as a three-layered process of interaction between "form" and "context" (Alexander, 1964). The former refers to the physical body of the artifact which is being designed, and the latter refers to the environment which sets requirements on it.

The top layer of this model consists of the "actual world", which seems to refer to the objective current state of the world and the artifact[135]; the middle layer consists of the designer's mental representation of it. According to Alexander, in non-computational design processes, the artifact is created by working on the middle layer, which is derived from the top layer as "a conceptual interaction between the conceptual picture of the context which the designer has learned and invented...and ideas and diagrams and drawings which stand for forms." The problem with this process, in Alexander's view, is that the designer's image or mental picture of the design is highly imprecise: in his words, it is "almost always wrong" (Alexander, 1964, p77). To rectify this, he suggests to add the bottom layer, which consists of a formalization of the designer's mental picture. (Fig. 8-3)

[133] For example, referring to piece of model cardboard as a building.
[134] See, for example (Rietveld & Brouwers, 2017).
[135] This layer is not explicitly defined by Alexander in this work (Alexander, 1964).

In Alexander's model, the mental picture is seen as a mere mediator, secondary to the computational level on which he places strong emphasis. He thus somewhat disregards the importance of mental representations in design activity, under the assumption that once the design problem is sufficiently clarified and formally represented, it can be dealt with computationally, without need for the designing agent.

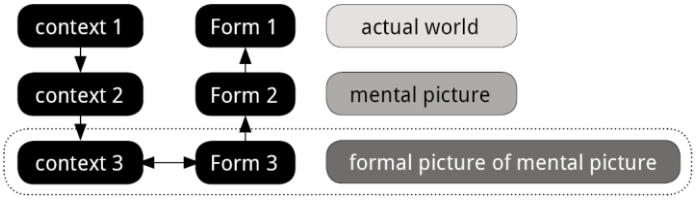

Figure 8-3 A three-layered view of design activity; as proposed by (Alexander, 1964).

Alexander's three-fold distinction between the objective state of the world, its mental representation by the agent and its computational formalization are important for establishing the basic relations between design as a human activity and computation. However, in attempting to convert design problems into computational representations, it somewhat throws out the baby with the bathwater. A key part of Alexander's thesis is that design problems are increasing in their complexity, to the extent where they exceed the mental capacities of human designers. While there is some truth in this statement, almost 60 years later it remains a fact that human designers are still superior to computational design systems in many design tasks, and perhaps above all in conceptual design. Therefore, if we appreciate designer's natural intelligence and ability to deal with design problems (see for example: Cross, 1999), it is hard to see how we can achieve human-level success in design, via this approach. Alexander himself admits that "It is not possible to replace the actions of a trained designer by mechanically computed decisions" (Alexander, 1964, p.75).

The problem lies in the fact that human behavior, which is highly adaptive, is not likely to be captured computationally in Alexander's bottom layer, which is strictly mathematical, formal and rigid. Indeed, his third layer consists of mathematical graphs which describe linkages and dependencies between variables. Such fixation strongly contrasts with later understanding of design activity, which emphasizes the importance of reflection-in-action for performing professionally (Schön, 1984). Moreover, it is well-known that human-driven design processes generally consist of a continuous expansion, exploration as well as re-conception of the problem and solution spaces (for example: Rowe, 1986, p.109). By removing interpretation activity from his model, Alexander's approach fixates the problem and solution spaces, resulting in a one-way process of conversion into formal representation, followed by computation. These are not in accord with our current understanding of how

design processes are navigated successfully by professional designers, which are rather characterized by high flexibility (Cross, 2001), thus exposing the weakness of his model.

In the 1990's, an important framework for design computing was proposed by John Gero, named as “the Function-Behavior-Structure framework” (Gero, 1990). Still widely used in the field to this day, this model served as a milestone in formalizing design processes as sets of basic entities and transformations between them. The value of this model lies in the fact that it enables to describe design processes as the product of low-level entities, which can be theoretically represented within a computational system. While the model did not include the important aspect of mental representation in design, it nonetheless marked an important achievement in the field of design computing, enabling to describe, formalize and inquire into design processes in a systematic manner.

Somewhat in parallel, a shift towards "situated" approaches for studying and understanding human activity has seeped into engineering paradigms. These approaches, which acknowledged the importance of the agent and its internal state, have produced successful designs for control systems which are capable of handling real-time tasks.[136] Accordingly, they inspired a reevaluation of our current models for design activity, leading to the expansion of Gero’s original framework.

In 2004, Gero and Kannengiesser proposed a model for design activity, termed as "the situated function-behavior-structure framework" (situated FBS), which is the current state-of-the-art model for situated design (Gero & Kannengiesser, 2004)[137]. In addition to the original components of function, behavior and structure, the new model consisted of three worlds: “external”, “interpreted” and “expected” (Figure 8-4). Alexander's "actual world" somewhat corresponds with the external world here, while his "mental picture" can be thought of as a mental construct involving both the interpreted and expected worlds.[138] In addition, a memory component is included, which accounts for the fact the all mental representations are continuously constructed and reconstructed within the agent’s memory, thus named “constructive memory”.

[136] See (Clancey, 1997), also refer back to 2.2.
[137] Refer back to 2.2.3.
[138] Since it is derived from the "actual world" based on our interpretation, while including our expectations regarding future states of the artifact.

Figure 8-4 Design worlds of the situated FBS; adapted from (Gero & Kannengiesser, 2004).

In this model, we see a shift towards acknowledging the importance of the designer's first-person perspective in describing and formalizing design activity. The representation of design processes now includes certain aspects of the designer's view of the design problem, describing design as a set of transformations between somewhat objective (external) and subjective worlds (interpreted, expected). Generally speaking, their model postulates that design activity can be described as a set of transformations between functions, behaviors and structures, across these worlds, while using the constructive memory.

While their model provides us with essential tools for modeling design in a realistic manner, it lacks in its ability to describe the designer's mental image which is formed during the process of interpreting structures. As we have explained and demonstrated throughout the work, during interpretation activity designers may develop a metaphorical image of the artifact.[139] This image cannot be represented using the situated FBS framework, for two main reasons: first it does not provide us with sufficient vocabulary for describing entities on the interpretive level (for example, the metaphorical roles of element). Second, it does not inform us with respect to how the mental image is structured by designers in-practice, within the constructive memory. Such knowledge must be derived empirically by studying design activity.

In this work we have addressed both of the above issues, by identifying several key entities which enable the designer to engage in interpretation on a metaphoric level, as well by utilizing empirical data for proposing a description of their organization into a coherent whole, reflecting and informing us regarding the mental image held by the designer. This resulted in the notion of NWs, which provides us with tools for describing how the designer views the structure metaphorically when designing. The nature of this image and its importance are described in the following sections.

8.3 Achievement

In order to elucidate the notion of NWs and their place in understanding design and interpretation activity, we briefly recap on our insights from the previous section.

[139] See Chapters 6, 7.

As explained above, Alexander rightfully acknowledges the need for a formal account of the designer's mental picture, for design computing[140] (Alexander, 1964). However, his model eventually does away with the subjective mental picture of the designer, replacing it with a rigid mathematical representation. Therefore, his account neglects the importance of the subjective perspective of the designer for achieving real-time success in design processes. Second, in a more recent work, Gero & Kannengiesser have embraced interpretive processes as integral to design activity (Gero & Kannengiesser, 2004). However, while their model is theoretically capable of accommodating the mental image of the agent, it does not tell us how the image itself is organized or structured. Accordingly, we are proposing an account which deepens our understanding of the mental picture itself. What exactly is the NW, and how does it aid in describing the mental image held by the designer, when engaging in interpretation activity?

First, when designers engage in conceptual design, they use certain design materials as representational devices. In this, they continuously engage in acts of "seeing as", in which the material objects are taken as "epistemically transparent" (Liddament, 2000).[141] In simple words, instead of the mere object itself, the designer "sees" another object, which appears as a mental projection facilitated by his/her subjective interpretation.[142] This experience is fundamentally private[143], and manifests itself via complex mental images in the designer's internal world.

The Biologist Jakob von Uexküll has proposed the notion of an "umwelt" to refer to the private sphere of existence of organisms in general, spanned by their possibilities for interaction with the environment. In his seminal work "A stroll through the worlds of animals and men", he has further proposed the notion of "magic worlds"[144], which we see as helpful in clarifying the nature of NWs. As an example for these worlds, he mentions children playing outdoors and seeing a tree as a demon, due to certain visual features which they associate with a scary face. Such experiences are, of course, determined by the interpretation assigned to the tree bark (von Uexküll, 1934). In the same manner, the designer's experience of the structure opens the door to "magic worlds", which are only experienced by him/her.

The existence of such worlds poses a problem for design theory and research. How can we begin to describe such private worlds which are solely experienced by the subject, but nonetheless shape design and interpretation activity?[145]. According to Fujii:

[140] Notice that, in this, he indirectly mentions the interpretive aspect of design.
[141] Refer back to 2.1.3.
[142] Recall our example of an architect working with a scale model of a building made out of cardboard; the architect "looks through" the cardboard and "sees" the future building.
[143] Of course, it may be shared by several individuals using language, to some extent.
[144] Previously mentioned in 7.6.
[145] See further in 8.4.

> *"It is essential to construct a bridge connecting ontologically subjective experience and epistemologically objective explanation so as to take up findings from the former for discussion in modern scientific inquiry aiming at public understanding of something"(Fujii, 2019, p.16).*[146]

Based on this, we rephrase the above question as follows: how can we bridge subjective experience and epistemologically objective knowledge of interpretation in design? Clearly, if we are to do so, we must make an effort to understand how designing is experienced from the perspective of the designer, during interpretation processes. Such an effort may give us a glance into the designer's internal world.

It is fair to say that Uexküll, mentioned above, has approached the study of worlds from a post-humanistic perspective.[147] As a result, he gave little attention to the uniquely human mental capacities of utilizing epistemic transparency and construct worlds of a representational nature. According to current philosophy of mind, one of the basic properties of our mental states is their "directedness" or "aboutness", i.e. the fact that they are directed at certain things such as objects, concepts, states of affairs etc.[148] Returning to the matter of interpretation in design activity, if the designer engages in mental states when interpreting a structure metaphorically, what is the content of his/her intentional states, and how is it organized?

The NW serves as a means for answering the above questions, by mapping certain components of the designer's subjective perspective in an objective manner, using symbolic descriptions. We would like to emphasize that the NW does not pertain to directly represent the mental image itself - it is rather a device for modeling some of the contents of the image, and the manner in which it is organized. Of course, some important mental aspects are not included in our account[149], and require attention in future research.[150] The key point here is that interpretation activity involves the attribution of certain qualities, features, roles etc. to the design elements, and that NWs enable us to map out complex interpretations formed by these and held by designers, during design activity[151]. In this, it opens the door to the agent's subjective perspective on the design situation, and how he/she metaphorically views and experiences the structure. The next section enables us to look into the organization of a NW as a reflection of the agent's intentional states.

[146] Notice that, while the above is expressed in the context of architecture, it applies to design activity as a whole.
[147] Generally referred to as biosemiotics.
[148] See, for example (Crane, 2003) ; refer back to 7.2.3.
[149] For example, the sub-symbolic level; see (Fujii, 2019).
[150] Further discussed in 9.2.
[151] Such mental images can be held explicitly or implicitly.

8.4 Narrative Worlds and Intentionality

In order to elucidate the manner in which NWs structure the designer's understanding of design activity, via their intentional states, we expand on an example from chapter 7[152]. In this example, an imaginary forest was seen by the designers, while engaging in interpretation activity. Figure 8-5 elaborates on the progression of the interpretation, as a series of consecutive steps. In this we have also added the aspect of "direction of fit", which characterizes intentional states according to Searle, as explained below (Searle, 2004). How does Figure 8-5 aid in taking the designer's perspective in interpretation?

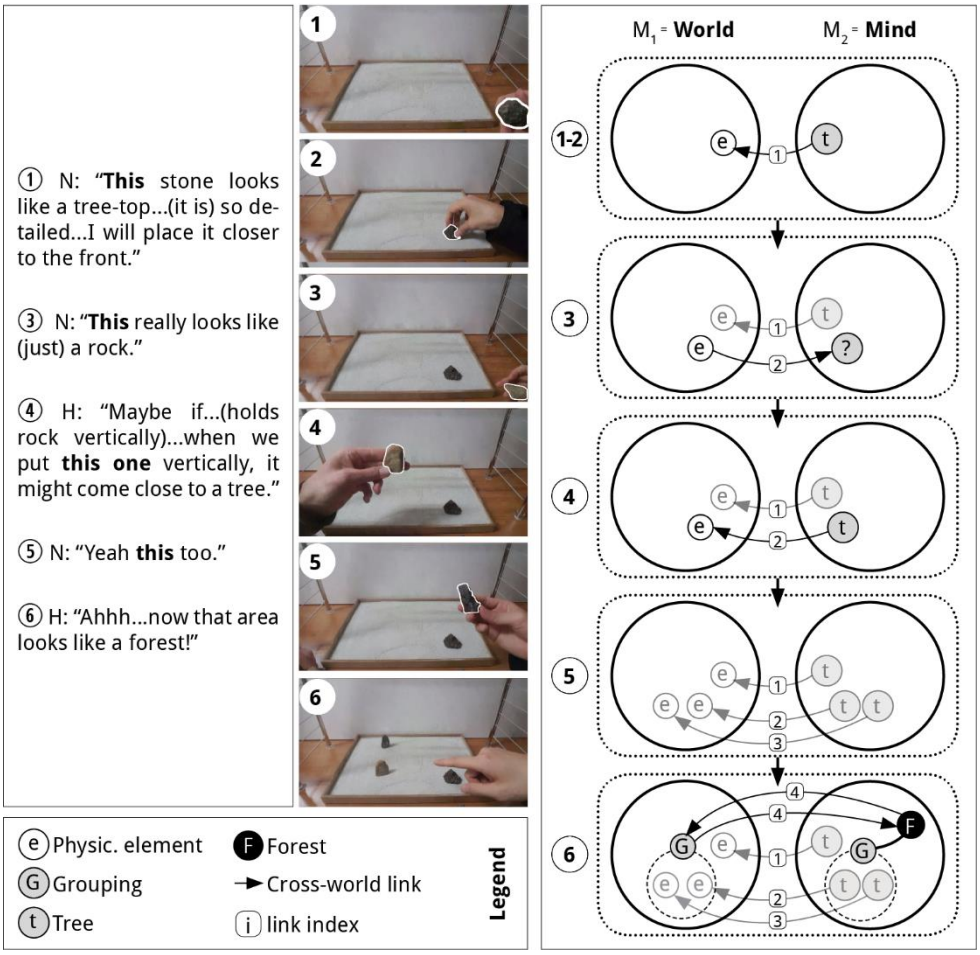

Figure 8-5 NWs as a bridge between world and mind.[153]

First, notice that while previously we have referred to the mental spaces M1 and M2 as "external world" and "NW", here we refer to them as "world" and "mind", to conform with

[152] Previously given in Figures 7-2, 7-9.
[153] This expands on Figure 7-2 by including the notion of "direction of fit" by Searle, indicated by arrows (Searle, 2014).

Searle's account of intentionality. Second, while the previous figures from the design session only reflected the final state resulting from the assignment of roles, here we see the actual process in which they subsequently appear. Third, while previous links between elements and their interpretation were non-directed, here they are directed. The directions of the arrows indicate what Searle refers to as the "direction of fit" of intentional states. In short, some intentional states deal with content targeted at matching the world which exists independently of them (referred to as world-to-mind relation), while others aim towards fitting the world into the content of the mental state itself (referred to as mind-to-world).[154]

By understanding Figure 8-5 in this manner, we can see how various events in the course of interpretation are reflected in it, as follows: when a designer assigns a role for an element (for example in states 1-2), he/she imposes an interpretation on it, in a manner of mind-to-world. Such assignment can be thus understood as a mental projection of subjective content onto the "objective" design elements. In some cases, the attempt for interpretation fails, and the object is perceived as is, in a world-to-mind manner (for example as in state 3).

Even more interesting, however, is that that such a description as in Figure 8-5 enables us to see how the understanding of the artifact is formed via a kind of weaving between the mind and the world, and raise deep questions regarding the dynamics of interpretation. This can be seen in state 6, where the designer points to the back-left area of the tray, and interprets both rocks there as composing an imaginary forest. Notice that, in this case, it is not clear whether the designer first visually perceived a gestalt which resulted in the grouping of the imaginary elements, or that the similarity between the imaginary trees caused the designer to perceive the gestalt. Accordingly, we have drawn two links indexed with the number 4, to represent this ambiguity. In this the NW both reflects intentional content (for example, by capturing the matching of grouping across the worlds, which is an essential component of the designer's understanding), as well as serves as a tool for further inquiry into fleeting events during the design, which may otherwise go unnoticed.

This account of interpretation as an intentional activity enables us to further restate and finally address the question raised in 8.3: consider an agent who employ "seeing as" during interpretation. If this agent engages in mental states which are directed, *what are they directed at*? First, it is clear that such mental states are not solely directed at the structure (see 8.3). It would be more accurate to say that the agent's thoughts are partially directed at the existing structure (world) and partly at the desired artifact (mind). For clarification, since the desired artifact does not yet exist, the designer's thought cannot be directed at it, but only at a mental representation of it. While some part of this representation may be derived rather directly from the physical object, certain aspects of it strongly depend on interpreting

[154] As examples for these different relations, consider the intentional states of belief and desire, accordingly.

and thus remain completely private. These private entities, such as roles, grouping etc., as we have described them, are organized as a symbolic construct in the designer's mental world. The NW enables us to clearly describe such constructs, and as such, facilitates a systematic inquiry into them.

8.5 Implications

We have proposed an approach for modeling certain aspects of the mental image used by designers during interpretation activity, framed under the notion of NWs. In addition, we have identified key-entities and processes which are essential for the study of interpretation of structures, each contributing to our efforts for understanding, modeling and eventually formalizing interpretation in design. The main implications are discussed below:

(1) **For design theory and practice, with emphasis on design cognition:** The notion of NWs may serve as a fundamental device for inquiring into the mental image held by the interpreting agent. This device may be used by design theorists dealing either with situatedness in design or with interpretation-in-action, for modeling the subjective view of the agent, with respect to external objects. Such modeling aids in visualizing and thus getting insight into the changing manners in which the agent understands the relations between the structure and its interpretation.[155] This also supports our initial claims regarding the potential of utilizing situated approaches to cognition for studying design activity.

Second, this work can serve as a basis for extending the situated FBS framework, to include not only descriptions of structures, but also those which indicate how agents conceptually understand them on a metaphoric level, within the interpreted world. This can aid in integrating the important aspect of metaphoric interpretation into current computational design models, which may result in increased flexibility and control within CAD systems for conceptual design.

Finally, NWs can potentially be used by design educators/practitioners as a conceptual tool for gaining insight into the manners in which design processes are driven by interpretation of structures. Donald Schön, a prominent researcher in design cognition, has suggested that performing professionally requires one to be aware of his/her current perspective, which structures both thinking and action (Schön, 1984). Yet, he did not suggest a concrete method for gaining such awareness.[156] Additionally, Suwa has proposed the idea "constructive perception" for describing the ways in which designers engage in interpretation, via organizing of spatial gestalts (Suwa, 2003). While he suggested that this interpretive ability

[155] Refer to Figure 7-11, for example.
[156] Perhaps since he presupposed this ability as a criterion for professionalism.

may be teachable via reflection (reminiscent of Schön's work mentioned above), he did not lay out a concrete process or method for doing so, i.e. for teaching designers how to reflect on their interpretations. Considering that NWs enable to organize and visualize the relations between objects, spatial gestalts and interpretations (which often remain implicit), we believe they have the potential for fulfilling this task of bringing one's interpretations into awareness. However, their ability to do so should be evaluated based on empirical data concerning the usage of NWs by educators/practitioners in their work.

(2) **For knowledge engineering and artificial intelligence in design:** Our modeling approach as well as the entities identified in this work [157], which are essential for systematically describing interpretation activity, may be used both by knowledge engineers and by developers of CAD support systems targeting conceptual design, for enhancing the capability of artificial agents to deal with the interpretation of structures.

Specifically, the above improve on our current ability to relate representations of structures with interpretations, using symbolic descriptions. Such descriptions can then be regarded as high-level features of the structure within the CAD system. It is important to notice that our proposed representation of interpretations consists not only of simple and direct couplings between structure and interpretation [158], but in fact have an internal logical structure. Accordingly, they can extend the abilities of current CAD systems to automatically reason during design processes, via simple integration with current inference engines.[159]

Furthermore, in a broader sense, our efforts and achievement can inspire researchers to engage in interpretation-oriented feature engineering, by drawing on our work both for reference regarding possible targets for formalizations, and for concrete examples of how such entities may be related on a symbolic level.

Finally, the notion of NWs invites the construction of design agents which can relate objective structures with subjective interpretations, by maintaining rich internal representations. These representations can then be coordinated with changes made to the environment, as the artificial agent engages in designing. This may help in the development of situated design agents, which, despite many efforts, are yet to be implemented within computational systems.

8.6 Back to the Garden

This work inquired into our human capacity for interpretation, and the ways in which it structures our thinking and action. In this sense, it has strived to be context-free. Accordingly,

[157] Refer back to Table 12.
[158] As in state-of-the-art systems; see, for example (Karimi et al., 2018); refer back to 2.4.
[159] As demonstrated in Chapter 5.

the previous section has considered the general implications of this work, for design cognition and for artificial intelligence in design.

In another sense, however, it is also contextualized: first, right from its inception, the research was greatly inspired by the traditional practices of JRGD; second, the design tasks which were studied, while not demanding strict adherence to traditional rules and practices, were in fact conducted in the context of JRGs. For these reasons, it seems fruitful to reflect on the relation of our results and the actual practices of JRGD, which originally motivated our inquiry.

Let us return to the fundamental instruction regarding rock placements in JRGs[160]:

> *"Choose a particularly splendid stone and set it as the Main stone…following the request of the first stone, set others accordingly" (Takei & Keane, 2001, p.181).*

Taking the above as characteristic of the Sakuteiki's instructive style, it is important to point out its somewhat loose nature, which demands designers to draw on their cognitive resources and actively participate in its execution. For example, while the instruction guides the designer to select a "splendid" stone, it does not define what a splendid stone is. The responsibility for interpreting this phrase, and acting accordingly, remains with the designer. When we initially presented this instruction, we concluded that the instructive style of the Sakuteiki renders JRGD as a proper object of study for this work, since it emphasizes the interpretive aspect of design activity. Note, however, that this instructive style also leaves us with a vague picture of *how* one can/should bring the instructions into action, when engaging in JRGD.

In fact, a close examination reveals many difficulties with the generality of the text as a design manual. For example: in the case where one sees several "splendid" stones, how should one choose between them? How is the chosen rock to be placed in the garden? What is actually meant by the "request" of the stone, and how should one "listen" to it? What criteria should one follow when attempting to set the other rocks "accordingly"?

Given that our goal is to formalize interpretation in design, is there any hope for capturing such complex design practices as JRGD for their implementation in computational design systems? Does our work tell us anything that can help us find our way through the mist of these convoluted texts, and enable to model JRGD activity? Surprisingly, the approach that we have taken in this work, which views design through the lens of situatedness (Clancey,

[160] Initially presented in 2.6.1.

1997; Clark, 1998; Gero & Kannengiesser, 2004) and intentionality[161](Searle, 1983), can both enlighten us regarding the difficulty with the instructions, and suggest a pathway for their future formalization.

When introducing the notion of NWs, we have viewed designing as a mind-world interaction. This view can shed light on the fundamental difficulty with the traditional manuals - what is confusing about instructions such as the above is that they intertwine the mind *and* the world, in a manner which implicit and therefore hard to disentangle (note that this may be have been deliberate, considering that these were secret texts; Slawson & ZoÌen, 1991). For example, when guiding one to choose a "splendid rock" as a first step, we intuitively understand choosing as a one-way cognitive task done *by* the agent *on* the world. A deeper look, however, reveals that one cannot hold to this simplistic view of the act of choosing - choosing depends upon perceiving, and perceiving means interacting with the world (seeing, touching etc.). Additionally, the possibility to perceive depends on the presence of the rock in a nearby place, so it can be perceived in the first place. Moreover, the process of perceiving itself is obviously insufficient for making a choice – one usually needs further cognitive processing, which often involves certain criteria for making the choice. [162] By this view, even the simple act of selecting a rock, which is presented in passing as an action to be executed *by* the agent, reveals itself as a complex time-extended event (Neisser, 1976), composed out of dense loops of interaction *between* mind and world.

With the above distinction in mind, and remembering Figure 8-5, we can start to break down and make sense of the traditional instructions, as sets of transactions between the mind and the world. As an example, let us continue with the instruction to "choose a…splendid stone" – this can be further broken down into processes of world-to-mind, in which one perceives and recognizes the existence of the rock and its properties (reflected in our modeling approach in its appearance in the designer's "external world"), followed by a mind-to-world response in which the designer interprets this rock as "splendid" or not (reflected by the link of the former and an element in the NW, which determines its interpretive role). In this manner, we can continue and inquire into the activity by studying such events of interaction, and the ways in which they interrelate during design activity. This points to the potential of our modeling approach for making sense of such complex design practices, by properly construing and visualizing them as systems of activity of agents within environments, with which they continuously interact through their intentional capacities.

Furthermore, the notion of NWs can specifically shed light on the ways in which our experience of JRGs as artifacts is structured under different interpretations. McGovern

[161] As an interaction between the mind and the world.
[162] These may be explicit or implicit.

emphasizes that the garden of Ryōan-ji[163] is "strongly multidimensional in its semiotic organizing principles and communicative purpose" (McGovern, 2004, p. 347). To support this claim, he provides us with various examples of different readings which the same elements afford – for instance, the lines in the sand can be seen either as "static" or as "flowing" (i.e. suggesting movement). He further proposes that the whole garden of Ryōan-ji can be approached and experienced differently via two distinct metaphors, which the viewer can employ; namely: (1) "rocks are mountains", or (2) "rocks are writing" (McGovern, 2004, p.357). Taking either of these as an interpretive device compels the viewer to project different sets of relations, groupings and meanings onto the design elements, thus resulting in a different experience of the structure. Our NWs can serve as practical tools for mapping the ways in which our mental representations are organized, as a consequence of embracing such different perspectives. In this case, each of the above metaphors may correspond with its own NW, in which the rocks are assigned with different meanings, under different gestalts. Therefore, our modeling approach can serve as a tool for inquiry into the ways in which the mental and the physical interrelate, by visualizing the effects of adopting specific interpretive perspectives on the general organization of internal representations in the mind of the viewer. Such work can draw on existing research regarding gestalt perception in JRGs (Van Tonder & Lyons, 2005) for describing the ways in which various configurations elicit different gestalts groupings (corresponding with clusters of elements in our mental spaces), which is essential for establishing a proper description of our experience JRGs.

8.7 Limitations & Possible approaches for Addressing Them

We discuss various limitations of the work, which we see as major hurdles in striving towards our goals. We suggest a potential approach for overcoming each of these, in future works on the topic:

(1) **Degree of complexity with respect to the design task and scope:**

- **Complexity of structures under consideration:** this work has attempted to lay the foundations for handling interpretation of structures in a systematic manner, which is, as thoroughly discussed in the introduction, a highly complex activity. Accordingly, we limited our scope to studying the interpretation of basic structures. By basic we mean that:

[163] Widely regarded as an exemplar of JRGs.

- elements of the structure cannot be modified (for example by dividing them, distorting their shape etc.), and in this sense they are "primitive" (see Qian & Gero, 1996)

- even in the case when several elements are joined into a group, we generally consider all elements as the members of a single structure which is analyzed. However, in reality, when we design, we create many different groups, which interrelate in complex ways (Qian and Gero refer to these as "substructures").

While the current design task does not allow designers to physically attach elements into sub-structures, it may nonetheless enable a deeper study of interpretation at a more detailed level, if we further include the various ways in which elements are visually grouped during visual perception (see Van Tonder & Lyons, 2005).

- **Complexity of design elements under consideration:** complementary to the above, to realistically model interpretation activity we may need to further consider the design on the element-level as well. As we learned from Schön, and later from Brereton, the choice of physical material in conceptual design is of great importance, since they shape the production of mental representations (Schön, 1992; Brereton, 2004). In our study, the level of abstraction is somewhat fixed and uniform. Therefore, it may be fruitful to enrich it by either adding new types of design elements, which are of higher or lower degree of abstractness (in the case of JRG these may be the moss patches, plantation etc.), or by conducting a similar analysis of a different design task, which demands working with changing degrees of abstraction (for example, architectural design which included both work with physical materials and sketches).

- **Focused aspect of design activity:** The current task places strong emphasis of visual aspect of artifacts, and the manners in which structures can be described on the basis of behavior. However, it does not sufficiently address the aspect of function.[164] We are considering to reformulate the task for designing Chinese Traditional Gardens, which place emphasis on rock formations and attend to functional aspects, such as the user's interaction with the architectural space.

- **Accounting for changes in viewpoint:** our design task was conducted in the context of JRGs. As previously mentioned,[165] these gardens consider the user's viewpoint in their designs, thereby embedding the architectural space with experiential qualities which are discovered via usage. The physical presence of users

[164] For a useful definition of function in design, the reader can refer to (Gero, 1990).
[165] Refer back to 2.6.1.

in the space and the changes in their viewpoint greatly enrich the interpretive aspect, since the elements can be seen from different angles and perceived under various gestalts (which invite reinterpretation). In our design task, subjects can view each rock from various perspectives prior to placing them in the space, by examining them with their hands. However, since their view of the garden remains somewhat fixed (as they are instructed to use a seat), rocks placed in the garden are generally perceived from a single point of view. In future research, it is desirable to enable the subjects to change their perspective of the physical model, as to facilitate consideration of the structure from multiple perspectives. In the case of subjects working in couples, this may require to work in a larger scale, since the current size does not afford to freely examine the model without intruding the partner's personal space. Furthermore, it may be necessary to integrate the fact that objects are interpreted differently from different perspectives into our modeling approach. This may be done by utilizing concepts from phenomenology, which deal with changes in experience as a result of shifts in perspective.[166]

- **Limited scope with respect to situatedness of the agent:** our work has drawn on the approach of situated cognition (Clancey, 1997; Clark, 1998) for modeling design activity (Gero & Kannengiesser, 2004). A key characteristic of this approach is the recognition of momentary states and circumstances as a driver of cognitive processes. Such circumstances were taken into account in the work, by relating interpretations with events which preceded them, and thus contributed to their emergence. However, it is difficult to overemphasize the relation of interpretation and meaning with the contexts in which they emerge. In this work, we have only done so in a limited manner.[167] It may be possible to further integrate such aspects of context using pragmatics.[168] Taking other perspectives, such as the effect of bodily states on cognitive activity, may require to harness current theories in embodied cognition.[169] We believe that, while there are numerous layers which interact in highly complex ways, some may have greater impact than others on interpretation activity in design.

(2) **Methodological Limitations in Data Acquisition and Analysis**

- **Reliance on protocols & the double-sided nature of language:** in studying interpretation activity based on protocols, we should consider that language is not merely used as a passive descriptive tool for interpretation, but has generative effects

[166] For example, see (Sokolowski, 2000).
[167] For example, by noting the domain of discourse.
[168] See, for example (Searle, 1969).
[169] Such as in (Shapiro, 2011).

on shaping interpretation activity.[170] This may be addressed either by including such effects in the model (subsumption) and/or by attempting to collect interpretation data only after the design session, as a reflection of subjects on their design process (neutralization).

- **Data analysis:** Considering the complexity of interpretation, processing the data and identifying patterns is highly difficult and time consuming. Therefore, a full formalization of the core knowledge acquired in this work is of high importance for future work, to enable computational analysis of the data. This will require the identification of a suitable knowledge representation, which can accommodate the key entities and relations which we have presented as essential for modeling interpretation activity.

(3) **Applicability of Findings to the Implementation of Computational Agents**

- **Selection among multiple interpretations:** our findings enable to represent and store interpretations within computational systems. However, since any structure may have multiple interpretations (see 1.3), constructing an artificial agent for interpretation would necessitate the additional capacity to select among multiple possibilities, given a certain structure. While human subjects do this rather naturally, the underlying mechanism seems highly complex, and involves an interaction between one's knowledge and mental states, as a response to current events. These, in turn, shape the agent's momentary preferences, which may determine (or at least constrain) the range of interpretations to choose from. We believe that here lies the key for integrating such capacities into computational systems, i.e. in the ability to prefer one interpretation over another, on a certain basis. Accordingly, we suggest to strive towards this goal by taking an approach of "human-in-the-loop", and inform the system regarding the preferability of certain possibilities over others. In practice, we may let human subjects feed certain preferences into a computer system, so that these can guide the filtering and selection of interpretations. This problem may be approached technically by integrating sub-symbolic computational modules (9.2), for capturing complex patterns of preference by taking input from the designer.

[170] For example, see (Vygotsky, 1986).

Chapter 9 Future Work & Conclusion

The previous section concluded with various limitations of the work, and possible ways to address them. This section discusses the concrete measures we intend to take in the subsequent steps of this research. The proposed notion of NWs has enabled us to form partial descriptions of the mental image held by the designer, during the act of interpretation. This image has certain explanatory power, aiding us to make sense of complex mental constructs and organize them within a comprehensible symbolic framework. However, considering our main goals (i.e. to deeply understand human cognition, and to implement our insights within artificial agents), to make progress, we believe it is essential to:

- formalize these descriptions into a computational model (for implementation in artificial agents), and
- complement the above computational model with a sub-symbolic layer of representation (for realistically describing the mental image).

The importance of the above for future research, and the manners in which we may approach them, are discussed in the following sub-sections.

9.1 Formalizing our Model

We describe one essential direction which our future work is planned to take. NWs, as well as their associated entities, aid in describing interpretation of structures in a systematic manner. As we have seen in Chapter 8, representing interpretation activity using NWs allows us to both organize key entities involved in interpretive processes, and visualize them as an intelligible construct. However, the current account of NWs lacks in two main aspects. First, in its ability to be implemented in a computational system, for enhancing artificial agents engaging in interpretation. Second, in our ability to expose complex patterns which emerge during interpretation activity, by reading their content. These are briefly discussed hereafter.

First, we strongly believe that implementing the ability to represent and reason with respect to NWs can greatly enhance current computational systems, and their capacity to engage in interpretation in conceptual design. At the moment, NWs are described as semi-formal constructs, by providing an account of their general entities and relations (mental spaces, design elements etc.). However, such an account is insufficient for implementation in a computational design system. A computational implementation would require a full formalization of the notion of NWs and the key entities which compose them. While this task

is feasible, further research is required in order to determine what knowledge representation framework can effectively host these worlds. As we have shown in chapter 7, interpretation may involve the existence of several, conflicting worlds. Therefore, it is important that the selected knowledge representation framework would have the capacity for representing such inconsistencies. Accordingly, we suggest to begin by closely examining systems associated with modal logic and possible world semantics.

Second, regarding our current ability to identify patterns within NWs - considering the cumulative complexity of the entities which appear during design sessions, processing the data and identifying patterns is highly difficult and time consuming. A full formalization of the core knowledge acquired in this work, may greatly aid in our future work, since it will open the possibility for representing and thus analyzing the data computationally. This further support our claim regarding the need for formalization of the constructs proposed in this work.

9.2 Beyond Symbolic Representation

The second direction we intend to take in our future work deals with the need for adding a sub-symbolic layer to our model. What do we mean by a sub-symbolic layer, and why should such a layer be added? First, it is important to introduce the difference between symbolic and sub-symbolic layers of conception. According to Fujii, when describing the manner in which agents experience the world, we can distinguish between three main conceptual layers: symbolic, sub-symbolic, and non-symbolic (Fujii, 2019). The symbolic layer generally refers to storing and manipulating symbols which stand for mental concepts, "grounding" them in memory and consciousness (see also Clark, 2005). The sub-symbolic level, on the other hand, refers to patterns of neural activity which underlie such symbolic assignments. We leave the third layer to the end of the discussion.

This work has approached interpretation of structures by focusing on the first layer, and provided an initial account for the symbolic representation component in mental images which are formed during interpretation. However, mental images are not likely to be completely reducible to pure symbolic descriptions. Our internal representations often contain and rely on additional sub-symbolic components, which involve complex associative patterns, mental imagery and more (see Kosslyn & Moulton, 2009). Therefore, drawing a complete description or representation of mental pictures in interpretation activity would necessitate to account for this essential, albeit complex, aspect as well.

In dealing with symbolic descriptions, we have taken the approach of formalization of key-entities involved in interpretation, followed by their implementation within logical inference

systems. Dealing with the sub-symbolic level will require taking a different approach, moving away from reliance on symbolic representation and towards sub-symbolic representation. This will demand the use of suitable computational methods, and may be facilitated by utilizing artificial neural networks, which have proven highly efficient in dealing with representation and identification of complex patterns, in both verbal and visual data. Of course, we do not mean to replace the symbolic level of description, which is necessary for reasoning etc. (see Newell, 1980), but rather to complement it via integrating the two. Integrated computational systems of this nature are often referred to as "hybrid systems", and the practice of forming such systems is referred to as "neuro-symbolic integration"

Current research in artificial intelligence frequently emphasizes the potential of such integration, i.e. of symbolic and sub-symbolic systems, for developing intelligent artificial agents. We quote Nils Nilsson's conclusion in his article dealing with the famous physical symbol system hypothesis:

> *"Here is my prediction about the future of physical symbol systems in AI: They will take on a partner (as Brooks proposes). AI systems that achieve human-level intelligence will involve a combination of symbolic and non-symbolic processing"(Nilsson, 2007, p.17).*

Finally, the third level of non-symbolic conception refers to our experiential awareness of the world and of ourselves. This aspect of our experience, which may reflect our highest level of consciousness[171], is far from being well-understood and formalized. Furthermore, it is unclear whether such awareness is a precondition for the intelligent behavior that we are trying to model. Hence, focusing on the first two layers seems sufficient in attempting to enhance current agents engaging in interpretation activity, and imbue them with higher degrees of intelligence.

9.3 Conclusion

We set on this project of studying interpretation with the double-aim of: (1) enhancing computational design systems for conceptual design, and (2) deepening our understanding of human cognition. The project has taken an integrated approach of utilizing state-of-the-art models of design-cognition along with empirical data from design activity. These have served a firm ground for developing a conceptual framework for understanding interpretation activity, from a holistic perspective.

[171] Commonly associated with the perspective of "strong AI" (Friedenberg & Silverman, 2006).

The basis for the conceptual framework proposed in this work is a notion which we have referred to as NWs. Generally speaking, these are mental environments in which internal interpretive content is organized, with respect to states of affairs in external physical space. These are further enriched by the identification and description of additional components which play key-roles in interpretation, proposed throughout the work.

Together, the above extend our understanding of interpretation activity in a twofold manner: first, by aiding in both organizing and visualizing certain aspects of the intentional content involved in it, i.e. world-to-mind relations which are essential for its understanding. Second, by demonstrating the potential of symbolic representation in systematically describing interpretive practices as partially logically structured constructs.

As discussed throughout the work, past models for design-computing have underestimated the importance of the subjective mental image held by designers, in describing design activity. Recent models for situated design, which have begun to acknowledge the importance of the agent's perspective as a causal factor in design activity[172], have yet to provide us with sufficient tools for describing the actual mental content involved in it. Such tools are especially important for future computational design systems which target conceptual design, as interpretation plays a major role within it. This dissertation provides us with a conceptual toolbox for studying, analyzing, and describing interpretation, while considering the perspective of the agent, and as such begins to fill this gap.

The new understanding which emerges from this study therefore opens the door to embracing subjective mental representations as potential components of future computational design systems. In this, it serves as a step towards "humanizing" CAD systems, by endowing them with representational capabilities central to interpretive practices. These can enhance their ability to automatically reason with respect to design representations, when engaging in conceptual design.

Beyond this contribution to computational design models, our thought-framework facilitates a systematic approach for the organization and visualization of symbolic components which are involved in interpretation practices. As such, it contributes to current research on design cognition, by augmenting our capacity to deeply inquire into interpretive processes, which are one of the cornerstones of the human capacity to design.

[172] This perspective can generally be thought of as his/her internal reflection of external reality (Fujii et al., 2013).

References

Abe, K., Sakamoto, K., & Nakagawa, M. (2006). A Computational Model of the Metaphor Generation Process. *Proceedings of the 28th Annual Meeting of the Cognitive Science Society*, (2), 937–942.

Akin, O. (1989). *Psychology of Architectural Design*. London: Pion.

Alexander, C. (1964). *Notes on the synthesis of form*. Cambridge: Harvard University Press, 28-45; 73-83.

Barr, A., & Feigenbaum, E. (1981). *The Handbook of Artificial Intelligence* (Vol. 1). Stanford: HeurisTech Press.

Beckman, S., & Barry, M. (2009). Design and Innovation through Storytelling. *International Journal of Innovation Science*, *1*(4), 151–160. https://doi.org/10.1260/1757-2223.1.4.151

Borges, J. L. (1975). On Exactitude in Science. In *A Universal History of Infamy*. London: Penguin Books.

Bowman, G., & Crawford, L. (2018). Narrative Reframing on Complex Projects. In *Academic Design Management Conference* (pp. 949–957). London.

Box, G. (1979). Robustness in the Strategy of Scientific Model Building. In *Robustness in Statistics* (pp. 201–236). Elsevier. https://doi.org/10.1016/B978-0-12-438150-6.50018-2

Brachman, R. J., & Levesque, H. J. (2004). *Knowledge Representation and Reasoning*. San Francisco: Morgan Kaufmann Publishers. https://doi.org/10.1016/B978-1-55860-932-7.X5083-3

Brentari, C. (2013). How to make worlds with signs. Some remarks on Jakob von Uexküll's Umwelt theory, *7*, 8–21. https://doi.org/10.4396/20130701

Brereton, M. (2004). Distributed Cognition in Engineering Design: Negotiating between Abstract and Material Representations. In G. Goldschmidt & W. L. Porter (Eds.), *Design Representation* (pp. 83–103). London: Springer London. https://doi.org/10.1007/978-1-85233-863-3_4

Brooks, R. (1986). A robust layered control system for a mobile robot. *IEEE Journal on Robotics and Automation*, *2*(1), 14–23. https://doi.org/10.1109/JRA.1986.1087032

Bruner, J. (1986). *Actual Minds Possible Worlds*. Cambridge: Harvard University Press, 3-105. https://doi.org/10.1176/ps.38.6.676

Burks, A. (1949). Icon, index, and symbol. *Philosophy and Phenomenological Research*, *9*, 673–689.

Cai, C., Tang, P., & Li, B. (2019). Inheriting Spatial Features of Chinese Garden Based on Prototype and Multi-Agent System. *CAADRIA 2019 24th International Conference of the Association for Computer-Aided Architectural Design Research in Asia*, *1*, 291–300.

Casakin, H. P. (2006). Assessing the use of metaphors in the design process. *Environment and Planning B: Planning and Design*, *33*(2), 253–268. https://doi.org/10.1068/b3196

Catania, G. (2007). Form-features for Mechanical Design and Manufacturing. *Journal of Engineering*

Design, *2*(1), 21–43. https://doi.org/https://doi.org/10.1080/09544829108901668

Chadwick, D. (1999). *Crooked Cucumber: The Life and Zen Teaching of Shunryu Suzuki*. New York: Broadway.

Charters, E. (2003). The Use of Think-aloud Methods in Qualitative Research: An Introduction to Think-aloud Methods. *Brock Education : A Journal of Educational Research and Practice*, *12*(2), 68–82.

Chatman, S. (1975). Towards a Theory of Narrative. *New Literary History*, *6*(2), 295–318. https://doi.org/10.2307/468421

Chen, M. chu, & Liu, Y. tung. (1996). Symbolic/neural hybrid approach to multiple shape recognition. *Proceedings of the Annual Southeastern Symposium on System Theory*, 158–162. https://doi.org/10.1109/ssst.1996.493490

Cheng, K. (2018). More situated cognition in animals: Reply to commentators. *Comparative Cognition & Behavior Reviews*, *13*, 49–54. https://doi.org/10.3819/ccbr.2018.130007

Childs, P., & Fowler, R. (2006). *Routledge Dictionary of Literary Terms* (3rd ed.). New York: Routledge. https://doi.org/10.1292/jvms.57.911

Chin, K. S., & Wong, T. N. (1996). Knowledge-based evaluation for the conceptual design development of injection molding parts. *Engineering Applications of Artificial Intelligence*, *9*(4), 359–376. https://doi.org/10.1016/0952-1976(96)00028-0

Chitham, R. (2005). *The Classical Orders of Architecture*. New York: Routledge.

Christensen, B., & Ball, L. (2016). Creative analogy use in a heterogeneous design team: The pervasive role of background domain knowledge. *Design Studies*, *46*, 38–58. https://doi.org/10.1016/j.destud.2016.07.004

Clancey, W. J. (1997). *Situated Cognition: On Human Knowledge and Computer Representations*. Cambridge University Press.

Clark, A. (1998). *Being There: Putting Brain, Body, and World Together Again*. Cambridge: MIT press.

Clark, A. (2005). Beyond the Flesh: Some Lessons from a Mole Cricket. *Artificial Life*, *11*(1–2), 233–244. https://doi.org/10.1162/1064546053279008

Coyne, R., Rosenman, M. A., Radford, A., Balachandran, B. M., & Gero, J. S. (1990). *Knowledge-Based Design Systems*. Sydney: Addison-Wesley Publishing Company.

Crane, T. (2003). The Intentional Structure of Consciousness. *Consciousness: New Philosophical Perspectives*, 1–27. Retrieved from http://discovery.ucl.ac.uk/13474/

Crnkovic, G. D. (2010). Constructive research and info-computational knowledge generation. *Studies in Computational Intelligence*, *314*, 359–380. https://doi.org/10.1007/978-3-642-15223-8_20

Cross, N. (1999). Natural intelligence in design. *Design Studies*, *20*(1), 25–39. https://doi.org/10.1016/s0142-694x(98)00026-x

Cross, N. (2001). Design Cognition. In *Design Knowing and Learning: Cognition in Design Education* (pp. 79–103). Elsevier. https://doi.org/10.1016/B978-008043868-9/50005-X

Daniels, Z. A., Frank, L. D., Menart, C., Raymer, M., & Hitzler, P. (2020). A framework for explainable deep neural models using external knowledge graphs. In T. Pham, L. Solomon, & K. Rainey (Eds.), *Artificial Intelligence and Machine Learning for Multi-Domain Operations Applications II* (p. 73). SPIE. https://doi.org/10.1117/12.2558083

Darke, J. (1979). The Primary Generator and the Design Process *. *Design Studies*, *1*(1), 36–44.

De Kleer, J., & Seely Brown, J. (2014). A Qualitative Physics Confluences, *24*(1984), 7–83.

Dewey, J. (1884). The New Psychology. *Andover Review*, *2*, 278–289. https://doi.org/10.5860/choice.47-0570

Dorst, K. (2015). Frame Creation and Design in the Expanded Field. *She Ji*, *1*(1), 22–33. https://doi.org/10.1016/j.sheji.2015.07.003

Dunbar, K. (1995). How scientists really reason: Scientific reasoning in real-world laboratories. In *The nature of insight.* (pp. 365–395). Cambridge, MA, US: The MIT Press.

Eco, U. (1986). *Semiotics and the Philosophy of Language*. Bloomington: Indiana University Press, 87-129.

Eco, U., & Paci, C. (1983). The Scandal of Metaphor: Metaphorology and Semiotics. *Poetics Today*, *4*(2), 217–257.

Eisenhard, J. L., & De Schepper, M. S. (2000). Approximate Life-Cycle Assessment in Conceptual Product Design. *ASME Design Engineering Technical Conferences & Computers and Information in Engineering Conference*. https://doi.org/DETC2000/DFM-14026

Ericsson, K. A., & Simon, H. A. (1980). Verbal reports as data. *Psychological Review*, *87*(3), 215–251. https://doi.org/10.1037/0033-295X.87.3.215

Fauconnier, G. (1994). *Mental Spaces: Aspects of Meaning Construction in Natural Language*. New York: Cambridge University Press.

Feigenbaum, E. A., Buchanan, B. G., & Lederberg, J. (1970). *On Generality and Problem A Case Study Using the DENDRAL Program*.

Feng, C.-X., Huang, C.-C., Kusiak, A., & Li, P.-G. (1996). Representation of functions and features in detail design. *Computer-Aided Design*, *28*(12), 961–971. https://doi.org/https://doi.org/10.1016/0010-4485(96)00027-9

Friedenberg, J., & Silverman, G. (2006). *Cognitive Science: An Introduction to the Study of Mind*. *Sage*. Thousand Oaks, 311-397.

Fu, K., Murphy, J., Yang, M., Otto, K., Jensen, D., & Wood, K. (2015). Design-by-analogy: experimental evaluation of a functional analogy search methodology for concept generation improvement. *Research in Engineering Design*, *26*(1), 77–95. https://doi.org/10.1007/s00163-014-0186-4

Fujii, H. (2019). MAAI: Dynamic Equilibrium in Architecture. *New Generation Computing*, *37*(3), 285–305. https://doi.org/10.1007/s00354-019-00068-w

Fujii, H., & Aoki, Y. (2003). Dual Deep-Structure to Associate a Shape with its Linguistic Description : A Hypothetical Framework and an Experimental Implementation, *2*(1), 115–121. https://doi.org/10.3130/jaabe.2.115

Fujii, H., Nakashima, H., & Suwa, M. (2013). Proposing Designology. *5th International Congress of International Association of Societies of Design Research*, 2232–2243.

Fukuda, T., & Saito, F. (1996). Motion control of a brachiation robot. *Robotics and Autonomous Systems*, *18*(1–2), 83–93. https://doi.org/10.1016/0921-8890(96)00002-4

Gallagher, S. (2001). Philosophical Antecedents of Situated Cognition. In *The Cambridge Handbook of Situated Cognition* (pp. 35–52). Cambridge University Press. https://doi.org/10.1017/CBO9780511816826.003

Garcez, A. d'Avila, Gori, M., Lamb, L. C., Serafini, L., Spranger, M., & Tran, S. N. (2019). Neural-symbolic computing: An effective methodology for principled integration of machine learning and reasoning. *IfCoLoG Journal of Logics and Their Applications*, *6*(4), 611–631. Retrieved from http://arxiv.org/abs/1905.06088

Garcez, D. S. A., Broda, K. B., & Gabbay, D. M. (2002). *Neural-Symbolic Learning Systems: Foundations and Applications*. London: Springer-Verlag.

Gärdenfors, P. (2000). *Conceptual Spaces*. Cambridge: The MIT Press. https://doi.org/10.7551/mitpress/2076.001.0001

Gentner, D. (1983). Structure-Mapping: A Theoretical Framework for Analogy. *Cognitive Science*, *7*, 155–170. https://doi.org/10.1207/s15516709cog0702

Gentner, D., & Smith, L. (2012). Analogical Reasoning. In V. S. Ramachandran (Ed.), *Encyclopedia of Human Behavior* (2nd ed., Vol. 1, pp. 130–136). Elsevier Inc. https://doi.org/10.1016/B978-0-12-375000-6.00022-7

Gero, J. (1990). Design Prototypes: A Knowledge Representation Schema for Design. *AI Magazine*, *11*(4), 26–36. https://doi.org/10.1609/aimag.v11i4.854

Gero, J. (1996). Creativity, emergence and evolution in design. *Knowledge-Based Systems*, *9*(7), 435–448. https://doi.org/10.1016/S0950-7051(96)01054-4

Gero, J. (1998a). Concept Formation in Design : Towards a Loosely-Wired Brain Model, *11*(1998), 429–435.

Gero, J. (1998b). Conceptual designing as a sequence of situated acts. In *Lecture Notes in Computer Science* (pp. 165–177). https://doi.org/10.1007/bfb0030450

Gero, J., & Fujii, H. (2000a). A Computational Framework for a Situated Design Agent , Part B : Constructive Memory. *Knowledge-Based Systems*, *13*(6), 361–368.

Gero, J., & Fujii, H. (2000b). Computational framework for concept formation for a situated design

agent. *Knowledge-Based Systems*, *13*(6), 361–368. https://doi.org/10.1016/S0950-7051(00)00076-9

Gero, J., & Kannengiesser, U. (2004). The situated function–behaviour–structure framework. *Design Studies*, *25*(4), 373–391. https://doi.org/10.1016/j.destud.2003.10.010

Gibson, J. (2014). The Ecological Approach to Visual Perception. https://doi.org/10.2307/989638

Goel, A. K., Vattam, S., Wiltgen, B., & Helms, M. (2012). Cognitive, collaborative, conceptual and creative - Four characteristics of the next generation of knowledge-based CAD systems: A study in biologically inspired design. *CAD Computer Aided Design*, *44*(10), 879–900. https://doi.org/10.1016/j.cad.2011.03.010

Goldschmidt, G. (1988). Interpretation: its role in architectural designing. *Design Studies*, *9*(4), 235–245. https://doi.org/10.1016/0142-694X(88)90009-9

Goldschmidt, G. (1991). The Dialectics of Sketching. *Creativity Research Journal*, *4*(2), 123–143. https://doi.org/10.1080/10400419109534381

Goldschmidt, G. (2014). *Linkography: unfolding the design process*. London: MIT press.

Goodman, N. (1978). *Ways of Worldmaking*. Indianapolis: Hackett Publishing Company, 1-22. https://doi.org/10.1139/g76-080

Groenewolt, A., Schwinn, T., Nguyen, L., & Menges, A. (2018). An interactive agent-based framework for materialization-informed architectural design. *Swarm Intelligence*, *12*(2), 155–186. https://doi.org/10.1007/s11721-017-0151-8

Gürer, E., Özkar, M., & Çağdaş, G. (2014). The role of interpretation in basic design. *A|Z ITU*, *11*(1), 158–173.

Hawking, Stephen, W. (2001). *The Universe in a Nutshell*. New York: Bantam.

Hay, L., Cash, P., & McKilligan, S. (2020). The future of design cognition analysis. *Design Science*. https://doi.org/10.1017/dsj.2020.20

Heidegger, M. (1962). *Being and Time* (Translated). Oxford: Blackwell Publishers.

Henderson, M. R., & Anderson, D. C. (1984). Computer recognition and extraction of form features: A CAD/CAM link. *Computers in Industry*, *5*(4), 329–339. https://doi.org/10.1016/0166-3615(84)90056-3

Herr, C. M., & Fischer, T. (2019). Design cybernetics and CAAD research. *Intelligent and Informed - Proceedings of the 24th International Conference on Computer-Aided Architectural Design Research in Asia, CAADRIA 2019*, *2*, 541–550.

Hey, J., & Agogino, A. (2007). Metaphors in Conceptual Design. *Proceedings of the ASME 2007 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference IDETC/CIE 2007 September 4-7, 2007, Las Vegas, Nevada, USA*, 1–10. https://doi.org/10.1115/DETC2007-34874

Hey, J., Linsey, J., Agogino, A., & Wood, K. (2008). Analogies and metaphors in creative design.

International Journal of Engineering Education, *24*(2), 283–294. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.161.4709&rep=rep1&type=pdf

Hilario, M. (1995). An Overview of Strategies for Neurosymbolic Integration. In *Workshop on Connectionist-Symbolic Integration:From Unified to Hybrid Approaches at the Fourteenth International Joint Conference on Artificial Intelligence*.

Holyoak, K., & Thagard, P. (1996). *Mental Leaps*. Massachusetts: MIT press. https://doi.org/https://doi.org/10.1207/s15327868ms1201_8

Hsiao, S.-W., & Tsai, H.-C. (2005). Applying a hybrid approach based on fuzzy neural network and genetic algorithm to product form design. *International Journal of Industrial Ergonomics*, *35*(5), 411–428. https://doi.org/10.1016/j.ergon.2004.10.007

Huang, H. Z., Liu, Y., Li, Y., Xue, L., & Wang, Z. (2013). New evaluation methods for conceptual design selection using computational intelligence techniques. *Journal of Mechanical Science and Technology*, *27*(3), 733–746. https://doi.org/10.1007/s12206-013-0123-x

Huhns, M. N., & Acosta, R. D. (1992). Argo: an Analogical Reasoning System for Solving Design Problems. *Artificial Intelligence in Engineering Design*, (February), 105–143. https://doi.org/10.1016/b978-0-12-660562-4.50010-8

Jastrow, J. (1892). Studies from the Laboratory of Experimental Psychology of the University of Wisconsin. II. *The American Journal of Psychology*, *4*(3), 381. https://doi.org/10.2307/1411617

Johnson, M. (1990). *The Body in the Mind: The Bodily Basis of Meaning, Imagination, and Reason*. Chicago: University of Chicago Press.

Jowers, I., Prats, M., Lim, S., McKay, A., Garner, S., & Chase, S. (2008). Supporting Reinterpretation in Computer-Aided Conceptual Design. *EUROGRAPHICS Workshop on Sketch-Based Interfaces and Modeling*, 151–158. https://doi.org/10.2312/SBM/SBM08/151-158

Jung, C. G., von Franz, M.-L., Henderson, J. L., Jacobi, J., & Jaffe, A. (1964). *Man and his Symbols*. New York: Dell Publishing, 1-94.

Kahlon, Y., & Fujii, H. (2019). A Framework for Concept Formation in CAD Systems: A Case Study of Japanese Rock Garden Design. *Computer-Aided Design and Applications*, *17*(2), 419–428. https://doi.org/10.14733/cadaps.2020.419-428

Kahlon, Y., & Fujii, H. (2020a). Framework for metaphor-based spatial configuration design: a case study of Japanese rock gardens. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing*, *34*(2), 223–232. https://doi.org/10.1017/S0890060419000295

Kahlon, Y., & Fujii, H. (2020b). Towards Modelling Interpretation of Structure as a Situated Activity: A Case Study of Japanese Rock Garden Designs. In J. S. Gero (Ed.), *Design Computing and Cognition '20*. Springer.

Kalay, Y. E. (2004). *Architecture's new media: Principles, theories, and methods of computer-aided design*. Cambridge: MIT press. https://doi.org/10.1080/17533015.2011.584886

Kannengiesser, U., & Gero, J. (2012). A Process Framework of Affordances in Design. *Design Issues*,

28(1), 50–62. https://doi.org/10.1162/DESI_a_00123

Kant, I. (1998). *Critique of Pure Reason*. (P. Guyer & A. W. Wood, Eds.). Cambridge University Press. https://doi.org/10.1017/CBO9780511804649

Kao, J. T., Bergen, L., & Goodman, N. (2014). Formalizing the Pragmatics of Metaphor Understanding. In *Proceedings of the 36th Annual Conference of the Cognitive Science Society* (Vol. 36, pp. 719–724).

Karimi, P., Grace, K., David, N., & Lou Maher, M. (2018). Creative Sketching Apprentice: Supporting Conceptual Shifts in Sketch Ideation. In *Design Computing and Cognition '18* (pp. 721–738). https://doi.org/10.1007/978-3-030-05363-5_39

Kelly, N. (2011). *Constructive Interpretation in Design Thinking*. The University of Sydney.

Kim, S. G., Yoon, S. M., Yang, M., Choi, J., Akay, H., & Burnell, E. (2019). AI for design: Virtual design assistant. *CIRP Annals*, *68*(1), 141–144. https://doi.org/10.1016/j.cirp.2019.03.024

Kintsch, W. (2000). Metaphor comprehension: a computational theory. *Psychonomic Bulletin & Review*, *7*(2), 257–266.

Kolko, J. (2010a). Abductive thinking and sensemaking: The drivers of design synthesis. *Design Issues*, *26*(1), 15–28. https://doi.org/10.1162/desi.2010.26.1.15

Kolko, J. (2010b). Sensemaking and Framing: A Theoretical Reflection on Perspective in Design Synthesis. In D. Durling, R. Bousbaci, L. Chen, P. Gauthier, T. Poldma, S. Roworth-Stokes, & E. Stolterman (Eds.), *Design and Complexity - DRS International Conference*.

Kosslyn, S. M., & Moulton, S. T. (2009). Mental Imagery and Implicit Memory. In K. Markman, W. Klein, & J. Suhr (Eds.), *Handbook of Imagination and Mental Simulation*. New York: Psychology Press. https://doi.org/10.4324/9780203809846.ch3

Krijnen, T., & Tamke, M. (2015). Assessing Implicit Knowledge in BIM Models with Machine Learning. In *Design Modelling Symposium Modelling Behaviour* (pp. 397–406). Springer. https://doi.org/https://doi.org/10.1007/978-3-319-24208-8_33

Krippendorff, K. (1989). On the Essential Contexts of Artifacts or on the Proposition that "Design Is Making Sense (of Things)." *Design Issues*, *5*(2), 9–39.

Kühnberger, K. U., Wandmacher, T., Schwering, A., Ovchinnikova, E., Krumnack, U., Gust, H., & Geibel, P. (2007). Modeling human-level intelligence by integrated cognition in a hybrid architecture. *CEUR Workshop Proceedings*, *277*.

Lakoff, G., & Johnson, M. (2003). *Metaphors We Live by*. London: The University of Chicago Press. https://doi.org/10.2307/414069

Lamb, L. C. (2008). The Grand Challenges and Myths of Neural-Symbolic Computation. *Dagstuhl Seminar 08041, Recurrent Neural Networks: Models, Capacities, and Applications*.

Lehtiranta, L., Junnonen, J.-M., Kärnä, S., & Pekuri, L. (2015). The Constructive Research Approach: Problem Solving for Complex Projects. *Designs, Methods and Practices for Research*

of Project Management, (1993), 95–106.

Leifer, L., & Steinert, M. (2011). Dancing with ambiguity: Causality behavior, design thinking, and triple-loop-learning. *Information Knowledge Systems Management*, *10*(1–4), 151–173. https://doi.org/10.3233/iks-2012-0191

Levinson, S. (1983). *Pragmatics*. New York: Cambridge University Press.

Lewin, K. (1936). *Principles of Topological Psychology*. (C. Morgan, Ed.). New York: McGraw-Hill Publications in Psychology.

Liddament, T. (2000). The myths of imagery. *Design Studies*, *21*(6), 589–606. https://doi.org/10.1016/S0142-694X(00)00003-X

Linsey, J. S., Laux, J. P., Clauss, E., Wood, K. L., & Markman, A. B. (2007). Increasing Innovation: A Trilogy of Experiments Towards a Design-by-Analogy Method. In *ASME 2007 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference* (pp. 145–159). ASMEDC. https://doi.org/10.1115/DETC2007-34948

Liu, C.-H., & Chen, Z. (2002). CAD-based automated machinable feature extraction. In *Proceedings of 27th Asilomar Conference on Signals, Systems and Computers* (pp. 558–562). IEEE. https://doi.org/10.1109/ACSSC.1993.342578

Lloyd, P. (2000). Storytelling and the development of discourse in the engineering design process. *Design Studies*, *21*(4), 357–373. https://doi.org/10.1016/s0142-694x(00)00007-7

Ma, K., Francis, J., Lu, Q., Nyberg, E., & Oltramari, A. (2019). Towards Generalizable Neuro-Symbolic Systems for Commonsense Question Answering, 22–32. https://doi.org/10.18653/v1/d19-6003

Maier, J. R. A., & Fadel, G. M. (2009). Affordance based design: A relational theory for design. *Research in Engineering Design*, *20*(1), 13–27. https://doi.org/10.1007/s00163-008-0060-3

Mansfield, S., & Richie, D. (2009). *Japanese Stone Gardens: Origins, Meaning, Form*. Tuttle Publishing.

Mao, J., Gan, C., Kohli, P., Tenenbaum, J., & Wu, J. (2019). The Neural-Symbolic Concept Learner. *Iclr 2019*, 1–28. Retrieved from https://openreview.net/pdf?id=rJgMlhRctm

Mason, Z. J. (2004). CorMet: A Computational, Corpus-Based Conventional Metaphor Extraction System. *Computational Linguistics*, *30*(1), 23–44. https://doi.org/10.1162/089120104773633376

McComb, C. (2018). Towards the Rapid Design of Engineered Systems. In J. Gero (Ed.), *Design Computing and Cognition '18* (pp. 3–18). Springer Nature.

McGovern, S. (2004). The Ryôan-Ji Zen Garden: Textual Meanings in Topographical Form. *Visual Communication*, *3*(3), 344–359. https://doi.org/10.1177/1470357204045787

McGrenere, J., & Ho, W. (2000). Affordances: Clarifying and Evolving a Concept. In *Proc. of Graphics Interface* (pp. 179–186). Montreal. https://doi.org/10.1039/b107967k

Miles, J. C., & Moore, C. J. (1994). *Practical Knowledge-Based Systems in Conceptual Design*.

London: Springer-Verlag.

Minsky, M. (1986). *The Society of Mind*. New York: Simon & Schuster.

Mitchell, J. R., & Radford, A. D. (1987). EAVE, a generative expert system for detailing. *Environment and Planning B: Planning and Design*, *14*(3), 281–292. https://doi.org/10.1068/b140281

Mohanty, S. (1997). *Literary Theory and the Claims of History*. Ithaca: Cornell University Press.

Mohebbi, A., Baron, L., Achiche, S., & Birglen, L. (2014). Neural network-based decision support for conceptual design of a mechatronic system using mechatronic multi-criteria profile (MMP). *Proceedings of the 2014 International Conference on Innovative Design and Manufacturing, ICIDM 2014*, *17*, 105–110. https://doi.org/10.1109/IDAM.2014.6912679

Moulianitis, V. C., Dentsoras, A. J., & Aspragathos, N. A. (1999). Knowledge-based system for the conceptual design of grippers for handling fabrics. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing: AIEDAM*, *13*(1), 13–25. https://doi.org/10.1017/S0890060499131020

Munjulury, R. C., Staack, I., Berry, P., & Krus, P. (2016). A knowledge-based integrated aircraft conceptual design framework. *CEAS Aeronautical Journal*, *7*(1), 95–105. https://doi.org/10.1007/s13272-015-0174-z

Murphy, K. M., Ivarsson, J., & Lymer, G. (2012). Embodied reasoning in architectural critique. *Design Studies*, *33*(6), 530–556. https://doi.org/10.1016/j.destud.2012.06.005

Nakagawara, C. (2004). The Japanese Garden for the Mind: The "Bliss" of Paradise Transcended. *Stanford Journal of East Asian Affairs*, *4*(2), 83–102.

Narayanan, S. (1999). Moving right along: a computational model of metaphoric reasoning about events. *Proceedings of the National Conference on Artificial Intelligence*, 121–127.

Neisser, U. (1976). *Cognition and Reality: Principles and Implications of Cognitive Psychology*. San Francisco: W.H.Freeman & Co Ltd.

Newell, A. (1980). Physical symbol systems. *Cognitive Science*, *4*(2), 135–183. https://doi.org/10.1016/S0364-0213(80)80015-2

Newell, A., & Simon, H. A. (1972). *Human Problem Solving*. Englewood Cliffs, New Jersey: Prentice-Hall.

Nilsson, N. J. (2007). The Physical Symbol System Hypothesis: Status and Prospects. *50 Years of Artificial Intelligence*, *19*(3), 9–17. https://doi.org/10.1007/978-3-540-77296-5_2

Onians, J. (1988). *Bearers of Meaning*. New Jersey: Princeton University Press.

Patrick, P. (2006). Design as Storytelling. *TechTrends*, *50*(4), 72–82.

Peirce, C. S. (1998). *The Essential Peirce*. (N. Houser, Ed.). Indiana University Press, 477-491.

Qian, L., & Gero, J. (1996). Function–behavior–structure paths and their role in analogy-based

design. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing*, *10*(4), 289–312. https://doi.org/10.1017/s0890060400001633

Rankin, M. (1988). Designing Thinking-Aloud Studies in ESL Reading. *Reading in a Foreign Language*, *4*(2), 119–132.

Rao, V., Moore, G., Udekwu, O., & Hartmann, B. (2020). Tracing stories across the design process : a study of engineering students ' engagement with storytelling in an undergraduate human-centered design course, 7342418.

Rietveld, E., & Brouwers, A. A. (2017). Optimal grip on affordances in architectural design practices: an ethnography. *Phenomenology and the Cognitive Sciences*, *16*(3), 545–564. https://doi.org/10.1007/s11097-016-9475-x

Robbins, P., & Aydede, M. (Eds.). (2009). *The Cambridge Handbook of Situated Cognition The Cambridge Handbook of Situated Cognition*. New York: Cambridge University Press.

Rowe, P. G. (1986). *Design Thinking*. Cambridge: MIT Press.

Salomons, O., van Houten, F., & Kals, H. (1993). Review of research in feature-based design. *Journal of Manufacturing Systems*, *12*(2), 113–132. https://doi.org/https://doi.org/10.1016/0278-6125(93)90012-I

Sánchez, V. G. C., Vergara, V. O. O., Salgado, G. R., & Domínguez, H. D. J. O. (2011). Do you want to be in fashion? Go hybrid using neurosymbolic systems. *IEEE Potentials*, *30*(3), 24–29. https://doi.org/10.1109/MPOT.2011.940234

Sarkar, S., Lore, K., & Sarkar, S. (2015). Early Detection of Combustion Instability by Neural-Symbolic Analysis on Hi-Speed Video. In *COCO'15: Proceedings of the 2015th International Conference on Cognitive Computation: Integrating Neural and Symbolic Approaches* (pp. 93–101).

Sassure, F. de. (1959). *A Course in General Linguistics*. (C. Bally & A. Sechehaye, Eds.). New York: McGraw-Hill.

Schön, D. (1984). *The Reflective Practitioner*. New York: Basic Books.

Schön, D. (1988). Designing: Rules, types and worlds. *Design Studies*, *9*(3), 181–190. https://doi.org/10.1016/0142-694X(88)90047-6

Schön, D. (1992). Designing as reflective conversation with the materials of a design situation. *Knowledge-Based Systems*, *5*(1), 3–14. https://doi.org/10.1016/0950-7051(92)90020-G

Schön, D. (1993). Learning to Design and Designing to Learn. *Nordic Journal of Architectural Research*, *1*, 55–70.

Schön, D., & Wiggins, G. (1992). Kinds of seeing and their functions in designing. *Design Studies*, *13*(2), 135–156.

Scott, B. (2004). Second-order cybernetics: an historical introduction. *Kybernetes*, *33*(9), 1365–1378. https://doi.org/10.1108/03684920410556007

Searle, J. (1969). *Speech Acts*. Cambridge University Press. https://doi.org/10.1017/CBO9781139173438

Searle, J. (1983). *Intentionality: An Essay in the Philosophy of Mind*. Cambridge: Cambridge University Press.

Searle, J. (1990). Metaphor. In A. Martinich (Ed.), *The Philosophy of Language* (2nd ed., pp. 408–429). New York: Oxford University Press.

Searle, J. (2004). *Mind: A Brief Introduction*. New York: Oxford University Press.

Shah, J. . (1991). Assessment of features technology. *Computer-Aided Design*, *23*(5), 331–343. https://doi.org/https://doi.org/10.1016/0010-4485(91)90027-T

Shapiro, L. (2011). *Embodied Cognition*. New York: Routledge.

Shortliffe, E. (1976). *Computer-Based Medical Consultations: MYCIN*. New York: Elsevier.

Simon, H. A. (1996). *The Sciences of the Artificial*. Cambridge: MIT Press.

Singaravel, S., & Philipp, G. (2018). Deep Component Based Neural Network Energy Modeling. In J. Gero (Ed.), *Design Computing and Cognition '18* (pp. 21–36). Lecco: Springer Nature.

Slawson, D., & ZoÌen. (1991). *Secret Teachings in the Art of Japanese Gardens: Design Principles, Aesthetic Values*. Tokyo: Kodansha International.

Smith, G., & Gero, J. (2001). Situated design interpretation using a configuration of actor capabilities. In J. Gero, S. Chase, & R. MA (Eds.), *CAADRIA 2001* (pp. 15–24). Key Center of Design Computing and Cognition, University of Syndey, Sydney.

Soegaard, M. (2002). The Glossary of Human Computer Interaction : 5. Affordances. Retrieved from www.interaction-design.org/literature/book/the-glossary-of-human-computer-interaction/affordances

Sokolowski, R. (2000). *Introduction to Phenomenology*. New York: Cambridge University Press.

Song, S., Dong, A., & Agogino, A. (2003). Time Variation of Design "Story Telling" in Engineering Design Teams. *Proceedings of the International Conference on Engineering Design (ICED 03)*.

Spivak, D. I., & Kent, R. E. (2012). Ologs: A categorical framework for knowledge representation. *PLoS ONE*, *7*(1), 1–52. https://doi.org/10.1371/journal.pone.0024274

Stempfle, J., & Badke-Schaub, P. (2002). Thinking in design teams - An analysis of team communication. *Design Studies*, *23*(5), 473–496. https://doi.org/10.1016/S0142-694X(02)00004-2

Stones, C., & Cassidy, T. (2010). Seeing and discovering: how do student designers reinterpret sketches and digital marks during graphic design ideation? *Design Studies*, *31*(5), 439–460. https://doi.org/10.1016/j.destud.2010.05.003

Summers, R., & Dybowski, R. (1994). Artificial neural networks: from black-box to grey-box modelling. In *Proceedings of 16th Annual International Conference of the IEEE Engineering in Medicine and Biology Society* (pp. 1061–1062). IEEE.

https://doi.org/10.1109/IEMBS.1994.415324

Sun, J., Kalenchuk, D. K., Xue, D., & Gu, P. (2000). Design candidate identification using neural network-based fuzzy reasoning. *Robotics and Computer-Integrated Manufacturing*, *16*(5), 383–396. https://doi.org/10.1016/S0736-5845(00)00017-X

Suwa, M. (2003). Constructive perception: Coordinating perception and conception toward acts of problem-finding in a creative experience. *Japanese Psychological Research*, *45*(4), 221–234. https://doi.org/10.1111/1468-5884.00227

Suwa, M., & Tversky, B. (1997). What do architects and students perceive in their design sketches? A protocol analysis. *Design Studies*, *18*(4), 385–403. https://doi.org/10.1016/s0142-694x(97)00008-2

Sweetser, E. (2007). Looking at space to study mental spaces. In *Methods in Cognitive Linguistics* (pp. 201–224). https://doi.org/10.1075/hcp.18.15swe

Taha, I. A., & Ghosh, J. (1999). Symbolic interpretation of artificial neural networks. *IEEE Transactions on Knowledge and Data Engineering*, *11*(3), 448–463. https://doi.org/10.1109/69.774103

Takei, J., & Keane, M. (2001). *Sakuteiki, Visions of the Japanese Garden: A Modern Translation of Japan's Gardening Classic*. Tuttle Publishing.

Tan, G. W., Hayes, C. C., & Shaw, M. (1996). An Intelligent-Agent Framework for Concurrent Product Design and Planning. *IEEE Transactions on Engineering Management*, *43*(3), 297–306. https://doi.org/10.1109/17.511840

Thagard, P. (2005). *Mind* (2nd ed.). Cambridge: MIT press, 1-58.

Tommelein, I. D., Levitt, R. E., & Hayes-Roth, B. (1989). Sightplan: An Artificial Intelligence Tool to Assist Construction Managers with Site Layout. In *Proceedings of the 6th ISARC* (pp. 340–347). San Francisco. https://doi.org/10.22260/ISARC1989/0043

Tong, C., & Gomory, A. (1993). A Knowledge-Based Computer Environment for the Conceptual Design of Small Electromechanical Appliances. *Computer*, *26*(1), 69–71. https://doi.org/10.1109/2.179161

Van Tonder, G., & Lyons, M. (2005). Visual perception in Japanese rock garden design. *Axiomathes*, *15*(3), 353–371. https://doi.org/10.1007/s10516-004-5448-8

Varela, F., Thompson, E., & Rosch, E. (1993). *The Embodied Mind*. Massachusetts: MIT press.

von Uexküll, J. (1934). A Stroll Through the Worlds of Animals and Men. *Instinctive Behavior*.

Vygotsky, L. (1986). *Thought and language*. London: MIT press. https://doi.org/10.3233/BEN-1992-5106

Watts, A. (2017). *Out ofYour Mind: Tricksters, Interdependence and the Cosmic Game of Hide-and-Seek*. Boulder: Sounds True.

Weick, K., Sutcliffe, K., & Obstfeld, D. (2005). Organizing and the process of sensemaking.

Organization Science, *16*(4), 409–421. https://doi.org/10.1287/orsc.1050.0133

Wilson, M. (2002). Six views of embodied cognition. *Psychonomic Bulletin and Review*, *9*(4), 625–636. https://doi.org/10.3758/BF03196322

Wilson, R. A. (2004). *Boundaries of the Mind: The Individual in the Fragile Sciences: Cognition*. New York: Cambridge University Press.

Wilson, R. A., & Clark, A. (2009). How to Situate Cognition. In M. Aydede & P. Robbins (Eds.), *The Cambridge Handbook of Situated Cognition* (pp. 55–77). Cambridge University Press.

Wittgenstein, L. (1958). *Philosophical Investigations*. Oxford: Basil Blackwell.

Yamada, S. (2009). *Shots in the Dark: Japan, Zen, and the West*. University of Chicago Press.

Young, L. F. (1987). The metaphor machine: A database method for creativity support. *Decision Support Systems*, *3*(4), 309–317. https://doi.org/10.1016/0167-9236(87)90102-3

Yumer, M. E., Chaudhuriy, S., Hodgins, J. K., Kara, L. B., Chaudhuri, S., Hodgins, J. K., & Kara, L. B. (2015). Semantic shape editing using deformation handles. *ACM Transactions on Graphics*, *34*(4), 86:1-86:12. https://doi.org/10.1145/2766908

Zamanian, K., Fenves, S., Thewalt, C. R., & Finger, S. (1991). A feature-based approach to structural design. *Engineering with Computers*, *7*(1), 1–9. https://doi.org/https://doi.org/10.1007/BF01208341

Zhang, D. (2018). Classical Chinese Gardens: Landscapes for Self-Cultivation. *Journal of Contemporary Urban Affairs*, *2*(1), 33–44. https://doi.org/10.25034/ijcua.2018.3654

Zhang, W. Y., Tor, S. B., & Britton, G. A. (2001). A prototype knowledge-based system for conceptual synthesis of the design process. *International Journal of Advanced Manufacturing Technology*, *17*(8), 549–557. https://doi.org/10.1007/s001700170137

Zhang, W., Yang, Z., Jiang, H., Nigam, S., Yamakawa, S., Furuhata, T., … Kara, L. (2019). 3D Shape Synthesis for Conceptual and Optimization using Variational Autoencoders. In *Proceedings of the ASME 2019* (pp. 1–10). Anaheim.

Zumthor, P. (2006). *Thinking Architecture*. Basel: Birkhauser Publishers for Architecture.

Appendix

A.1 Instructions Given to Subjects in Individual Sessions

The observer opened each session by asking the subject to take a seat in the chair next to the desk. The following instructions were then read from a tablet device, one by one, making sure that the subject understands each item:

- In front of you there is a tray with sand and a box with rocks to be placed in the tray.
- Please use the above to create a design for a miniature garden.
- Please refrain from placing one rock on top of another, or outside the sand tray.
- Other than that, the activity is generally free of constraints.
- Accordingly, the design may or may not have a theme or "concept".
- The total time available is half an hour; this may be extended if you wish to continue.
- During the whole activity, you are asked to use the "think-aloud" method.
- In order to become acquainted with this method, we will begin with a short practice session. Please find and pick up a rock which you like. While doing so, try to explain why you chose it, what is interesting about it etc., as you go.

Notice that the last instruction was given only for subjects who did not have previous experience with designing in a think-aloud style. Following these, the observer asked the subjects if they had any questions, and answered these questions. Typical questions were "are we expected to use all rocks?" and "do we need to make a traditional garden?". The observer clarified that, except the above, there are no additional demands or expectations from the design. When all questions were answered, the subjects were instructed to begin designing.

A.2 Transcripts from Individual Sessions

We provide the full transcripts from the individual design sessions below. Each sub-section corresponds with one full design session, by a single subject. When the subject produced more than one design solution, we have separated the transcript into compositions, each introduced in curly brackets in the form {composition no., starting time}. For the first

composition in each session, the starting time is omitted. Additionally, the observer's comments appear in square brackets, for example: [a comment].

A.2.1

{1st composition} I want to make them follow one rock, like that. I try to make the color in a good balance like this, maybe these two are dark and this one is a little bit whiter than that one, but I think maybe this one should be bigger, to make it more balanced. That one is too big…like that. [so you're thinking about the color and also the size] yeah, and also I gave them a theme, and everything maybe follows the theme [so the leader is the big one and then you try to match them with the big one] yes..[that's nice] also in some rock gardens there is not just one group, so maybe I can make another one to balance all the things, all the rock balance, maybe like….and it's like they're two face to face, but its' not so good because they are sharp but this one is like a round rock [because its round you feel it doesn't fit?] yeah, but this one is good in size, but the color maybe…maybe should be whiter, like that, I'll just use this one. I should add more rocks to balance, should be like that…maybe here is like a triangle, like this, and also the size of each group. [ah, so looking at the group as one pieces] yeah, I like the size of it, but it's really not suitable for all of these rocks [I really agree], maybe like this. And also, for each small group I try to make some look comfortable, and maybe that depends on the direction of each rock [so you're trying to adjust the direction inside the group] yeah, but this one is not that good, maybe this one is too big, put it just like that maybe. Maybe like that, make it smaller and this one looks bigger [I think it's a nice combination]. Maybe I can make a new theme

{2nd composition, 3:50} I really like that one [the big one?] yes, because I think the shape is good, and it's like its telling something [yeah it has many sharp corners]. This one also looks good, it can be the main, ah… the main stone in the next theme. Because, its also like that, it has some story [you see something special in this one…] yes [so what do you think is special in this one] I think it's like an elder man or an elder woman who has a lot of stories that we can see from his facial expression, his face is expressing something, and maybe he has suffered a lot of things, that we can see from this small, how to say that? [bumps?] yeah, and it will be the leader, and maybe for that he should have some…some…next generation around him [you mean the children…] yes the children are listening to his stories [I like you story] yeah the are sitting around. And I think what is important is the position of each small stones, because just now I want to put, I'm thinking about to put it here or here, but if I put that in that position, it looks not balanced, it look not comfortable for me, but if I put it here it looks balanced, but because of the theme, that the children are listening to the story, if I put it here maybe it's not so suitable for the theme, because of they are listening they should be face to face, but maybe it's not a face to face position, but for the balance it looks good. Maybe I need

some small pieces, maybe that's enough. Maybe I don't even need this one, maybe just like this [when you think about the balance, what is more important for you? You think about the position?] hmmm, yes position and size, and the size should be someone bigger and someone smaller like this, and the medium one, they are like maybe something to adjust the whole balance of these stones [and you're always thinking about the smaller ones] yes, smaller ones, maybe we can say that each kind of stones has their rules, the bigger one maybe represents the theme, and the smaller one maybe represent the balance, to help complete the theme, and the medium one, adjustment, to supply the whole theme as well as balance maybe, hmmm maybe we can change to another? [yeah we can do one more]

{3rd composition, 9:00} this one should stand, that's is like a background of something, like it is holding something, hmm…...maybe because I chose this one first, so the next stones I choose should be smaller ones, but if I didn't decide to use this one at first, maybe I can use some other bigger stones, and so this one will not be necessary, because of the balance [so when this is the first one, you're thinking about this like the main part of the composition, so you don't want to put something which is bigger, because it changes the…] yes, because it will also shatter its function [I understand]. The color is not balanced, and I think this one can also be a new theme, like its also telling something [yes, the shape is kind of special I think] and this one also, if you can give it a story, you can use it as a main one. Maybe here, and then under the shelter of the bigger one, it will not stand…[maybe we can just put something behind, ah that's good]. And also, for each small piece you can change or adjust the position or the angles of it, and it will give some different kind of insight I think, maybe like this, like this one it looks like it steeps down this side, and this one to this size [so each rock has its own direction] yes, but they are both pointing to the center. Maybe I can also still adjust it…[the smaller one are hard to handle] sometimes you can't really find a suitable one or a perfect one, this one…the shape of this one is good, but the width is a little bit…not so good, that's just like this, in two directions. That looks not good….[I think its interesting…when you feel it's not good like in this case, do you have any reason?] hmmm…reason…[if you just feel that, that's also ok…] just feels not comfortable, emotional feeling, not comfortable [I get it].

{4th composition, 13:10} when I see this one, I think it should be accompanied with some plant, some green stuff [around it?] yes, I don't know why. Maybe because I'm under the influence of Chinese gardens, I get this idea [ah they put some plant around the rocks…] yeah. Not good… [you don't like this combination?] I don't, don't like it very much, maybe its my preference that one big one, one main one, should be with some small pieces, maybe here, because it looks like this side is bigger and this side is small, so I just get the balance of the whole thing, so I add something here, so it will be balanced, like big and big, a lot of things and a lot of things…maybe just these two can be a combination? [Ok].

A.2.2

{1st composition} So I picked the first rock as this one, because among all other rocks, it kind of has a different kind of color, which is lighter than others, and I guess it is the most irregular shaped rock, hmmm, to me. I don't know where to put it so I put it around the central part of this tray and, just thinking about this…the second one I picked in terms of the size it's a similar size, and to in order to create the contrast I guess, because I don't know where to start, but creating a contrast it might be a start of the design, for me. [that's nice] so the color you see its quite different, it creates this contrast. In terms of the position of this second rock, I put it on the other side which is kind of symmetrical [it's true, its symmetrical in the whole space] yeah, but now I'm thinking about the third one…yes, for the third one I also picked a similar shape, not a similar shape but same kind of color, oh same kind of size, and the color tone is also a bit different. I think that will be my first try of this garden design, well it's just three rocks [it can also be just three] yeah, yeah I'm not sure but my perception towards rock gardens in japan its kind of three or four, but not a lot of rock [that's true]. I think these three rocks, and the size of rock is kind of proportional to the size of the tray, and…as I explained why I put them where it is, about the first two rocks, the third rock I just put it a around, a bit to the left of the three, because if I put it in the middle it will be a regular triangle, and that doesn't look like a nice design to me [so you prefer it to be asymmetrical] yeah [ok]. Yeah I mean a regular triangle is more like a symbol to me [ah a symbol for something] yeah a symbol for something, so its not a good design to me, just aesthetically [ah because it makes you think about the symbol] yes, and that it's just too regular for me [that's a nice insight]. Yeah, because also, because I know I have three opportunities to design this kind of, this garden for today, so I want to try a different color for the first time [that's nice, so each rock has a different color, and together they create something]. Yeah, it's all around the center of the tray, and yeah, I think, when I look at the tray, my focus first of all is on the center part of this tray. So I think my first perception and my intent just makes me want to put something around there [yeah, it feels maybe very empty so you want to put something in there…] yeah or I'm not sure what to do actually, so I probably focus on the center more, rather than the corners [yeah I think as a starting point it makes sense to me too, so do you want to try another one] yeah [ok so let's clean that up].

{2nd composition, 4:50} Hmmm…can I also explain the reason of why I didn't choose something? [whatever comes to your mind, shoot]. So, I just want to try a smaller rock, and see how the proportion looks on the tray. Yeah, second one…hmmm…probably this one, and yeah, I tried to put something in the corner, instead of the center part [ah that's nice, going in a different…] direction I guess…[yeah]. Let's see, I want to see what kind to try out, a design that is all the same color tone rocks this time, this one is a bit darkish, yes…probably around here. Not sure, I think I'm…trying to think about, look at this rock as a dot, and try to connect them together in my mind by lines [ah so there is a connecting line that is invisible,

like you're imagining] yeah, I'm imagining some kind of like, you know, I think… yeah I guess that's it for my second trial. [can you evaluate it somehow? For example, what do you think about it in comparison with the previous one?] I don't know I kind of prefer three rocks I guess, for the size of this tray, three rocks with that big of size, kind of looks perfect to me, and I think that the size this time is a bit small, yeah I don't know why but it makes me feel out of proportions [ahh, so you prefer this less than the other one] yes, sure. And also there is some kind of rock like this, kind of a round shape, so I prefer all the rocks with the same [like the same kind of contour] yeah contour yeah, so if I put this one it's going to look a bit strange [yeah, maybe it will not fit with the other ones, like it doesn't belong in the group] yes, and also like as I mentioned, I see this rock as a dot, and considering why I finished, it's because that the line kind of finished from one side to the other side [ahhh, so there is a connecting line here] yeah, and I think that if I put another one, it just gets the line to another direction, which doesn't make sense to me, but, yeah [yeah, I can feel some direction in here from your design, and I think it's also a consideration] yeah [but I think it's quite nice, do you want to try a last one?] yeah sure.

{3rd composition, 9:31} Yeah ah, I think this is the most beautiful rock to me, among all other rocks, because this one has more kinds of regular detail and contour, compared to.. [ah yeah] how do you say? Its more like a huge rock that you can climb to [ah you can imagine it like a space] yeah [or some…] yeah and this makes me imagine all this tray and the rocks like a small miniature, rather than a real-sized garden, so I kind of…[ah that's nice, so something about the rock makes you think like it could be a very big one] yeah because I can imagine myself during climbing a mountain and I can see this rock, because I guess I, like around the river in the mountain I can imagine and it reminds me of some rocks I use to climb to, which looks kind of cool [that's nice, you're not the first person to like this one by the way, yeah, I think it's special] yeah it's kind of, and it's the largest one [yeah that's true]. So…hmmm, this rock, not really sure, just see how it looks and give it a try. Yeah, ummmm, I think that's it for my third one [yeah, so what do you think about it aesthetically, when you look at this, is this satisfying for you]. Yeah as I said, it looks like a miniature to me right now, and you can see they all have kind of flat tops, compared with other ones which are pretty irregular, and I still prefer a number of rocks which is less than four. Probably three is the perfect number of rocks in this size of a tray, for this size of a tray [yes, I know what you mean, what do you think about the flat top, what is good about that or special in this case for you? I can also get some ideas, but...] to be honest it looks better, aesthetically for me, compared to [showing a different rock] [ahhh] yeah this is special, but, and as I said I picked this one before because it is special, it has the most irregular shape, and its kind of coarse compared to, oh yeah I guess the texture is different I guess [oh that's true, the ones you picked are a bit smooth] yeah smooth texture, and kind of fine like, compared to others. And also for the position, the composition of the whole small garden, I think yeah, I still prefer ummm, that

they get a bit close to each other, hmmm, which made more sense to me compared to, can I move this rock? [yeah, definitely] compared to something like this. Because if you consider the garden, and look at the garden, I think the rock is one of the main characters of this garden. Once you put them in two…the focal point in the garden is…[yeah, I know what you mean, definitely]. If I take this one here, yeah it might be like much like much scattered, it looks might better than, when they're together [I agree]. Yes, yeah and also…yeah I guess also like compared to my second trial, as I tried to connect by a line and to align them in some kind of way [yeah] I think that ummm it doesn't work very well, I doesn't look very well, looks very nice compared to this one, so I tried to get back to the, like, how to say, form some kind of pattern [yeah go back to the style of the first one] yeah, but I still prefer it in a regular pattern like this [that's very nice].

A.2.3

{1st composition} Ok, ummm, at first I have to think about my target, and who I design for, and also what kind of scene I want to create, still I'm not familiar with Japanese garden, but I wanted some garden that can be interactive with people, so people can actually go inside [yeah] especially for like kids, can go inside and play around and walk there and here [yeah]. So instead of building a scene only to display, I want to build a more active feeling, so I will pick a smaller one, not a big one, so create some like a small tiny space for people to walk around, and also, I was trying to think that, what kind of a scene I want to create. Personally, I really like city, like a very modern city like Tokyo and New York, [yeah] but the garden is very peaceful something, so I want to create somehow like a contrast between the tradition and the modern, so I want my garden to be very…you know, like you can sense a modern image in the traditional ones. So to symbolize the image of city [yeah] I will pick some bigger one, not to big, to create diversity of the scene, so firstly I would pick some bigger thing to help create the, ummm, framework, for example: I picked this one, since I think it looks like, how to say, a building, a tall skyscraper, so it like give a imagine of a…and also the shape is very straight, and also beyond that, I began to imagine what was around the skyscraper. I guess there should be a square for people to like, gather here [yeah] and to have some event, so for the space that around the skyscraper, for me I will keep it empty, and also have some smaller one besides the skyscraper, because I want to create like a street, the conception of street, for people like to recognize, to have a, ummm….can I change? [definitely, its very flexible. For you the other one is also like a building] yeah like a building, but to create some difference in height, to sense like a real situation [yeah]. I imagine the city should be like, I want to create like an ideal environment, where you can sense modern and also you can sense the feeling of tradition [yeah] so it's very open and diverse. I want to give something like a community, like this part, the center part is very modern, but I want to create somehow there,

maybe it's like subculture area that you can [ohhhh] that you can sense they may have some traditional event, or some like, community, like hidden community [yeah] so they will have some even smaller, even more smaller one here, so the, when people go there, they will sense quite a very different place from the center, and also, then I was thinking that this is a city, this is a center, and this is a hidden space, and what else should the city have, I began to think [yeah]. Actually it's a difficult question, hmmm, maybe at the center of the community are given I imagined, quite serious, so maybe I should give some places that are more like crazy, more like … for people to relax, so I want to pick some rock which has quite like a strange shape, not like a building but like a maybe I would position the rock like laid down, so it can create something like a park or like an amusement facilities, so I deliberately try to find some rock that some quite a different shape with others, and I picked this one, because this has a round shape, and quite different with other shapes [ah the shapes of the other ones] yeah, so I pick here, if I put here, and I find that and I realized after I put it there, this area itself becomes a small garden-like, so its like a mini garden in a mini-garden [laughing], so actually its quite interesting to have that. So, it can create like three areas, it now creates three areas – here, here and here. But the thing is that I found, how do you say, the…I put the rocks quite concentrated in the front part [yeah] I think maybe if I put something in the back part, will be interesting as well, so I begin to think what can I have in the back, usually what's in the back, hmmm so I've [what in the back in the city?] yeah, in the city. So I try to recall from my memory that all the cities I like, and think, I memorize that I was travelling in brazil, and the city was covered, was…there was a big mountain behind the whole city, so this kind of connecting the urban and the nature is very interesting, so I think there's like something symbolizing the nature, that behind this kind of very human culture, seeing this contrast will be very interesting [ahhh] so I began to check if there is some rocks that is significant different, either the size or the shape to all these rocks behind, so I grabbed the biggest rock and tried to, because this rock is the biggest one in all the rocks [yeah definitely] and also if I position it in a quite in a certain angle, and it can resemble something like nature, like a more mountain or something like a Fuji-san or something like that, so I try to put it there, okay [so for you, what makes this one resemble the mountain?]. Because the shape is like an angle [aha] like a triangle [ahhh, this shape] yeah, and also the huge difference between, of the size between the other rocks, yeah because it is quite like, very, how to say, a very different scene, in the whole scenery, so it makes people to, for me it makes me notice the difference between it and other rocks [yeah] so I put it there, and I try to look in a different angle, and I think yeah, it's quite has a different distance, and it has a different size, so maybe like it symbolizes a city with like a nature background or something, so I count, there is like, for now there is nine, oh seven rock, so I think its probably done [oh that's very nice, that was a very nice one, we can have five more minutes, maybe a small one?]. Turned over from the beginning [yeah, a completely different one] yeah of course I'd like, I want to do [we

can remove] we can remove now? [yes, I will re-create this later using the data from the top view] ah, that's great. Do we need to shake this? [maybe let's shake it a bit]. You can start

{2nd composition, 11:08} yeah, for this time I design something that is very three-dimensional city, people sit inside, so for this time I was thinking if I could create an illusion for people to, how to say, ummm, how to say, create an illusion that makes them think that it is either the right space or not, right dimension relationship or not. I'll try to, like in the dream or like in a game, because the space dimension is totally different from reality, so I think If I could create a sense of 2d, or like a…do you there an old game like Mario? [yeah] the space there is 2d, its two dimensions [yeah] so I think how to create that, so when people sit there, they will lose, they will lose the feeling of height, but only feel the horizontal thing [yeah] so in this way, I try to recall what will happen in Mario game [laughing] when people jump and when people go, but they can only move horizontally [that's true, like left and up] if I create ummm….it's very difficult [it's quite difficult] I picked a very difficult topic [it sounds difficult, definitely] yeah, it's very difficult, can I think a bit [yeah, take your time]. [You can also make something without a theme if you want] yeah [that's something that's also good] yeah [but if you would like to have a concept that's also nice]. I think that I can try during making the thing [hmmm] yeah I have another idea, maybe it's like, maybe it's a little bit there is something In common with Mario game [yeah] the thing is that I want people to lose their sense of direction, lose their sense of their cognition of the space, until the very end they can't sense how the space looks like. So I try to want to create a space that lets you feel lost, so I will need to, some rocks with a similar size [yeah] because in order to make them lose their way to…like memorize their route, and also to block their views of the whole thing [yeah] so I tried to pick some rocks with a similar size, and also with a similar shape, in order to make them, ummm, lose their direction, and also I need to make sure that the height of each rock is enough, it's the height of the people, so maybe like this one, because I only have ten rock, so I can design like a short journey [yeah] and the short journey is like around the side of the [ahhh] yeah like imagine that the people enter there, [yeah] and this is another one, like humans…people enter there. But they will have, less…they will perceive less other that what happens in the center, and until they go, until they go in the center, they can't perceive something. But I want to, after I create this short path, I want to like give a surprise, that after you…this is also like something in a game, that after you finish all the route you will see something [ahhh] you will see some difference [yeah] like from the beginning. So I try to pick something that symbolizes something like success or something, like symbolizes ummm…success or something [yeah its like the prize] yeah prize [for completing the…] so I want to find something that looks very monumental, like big, I guess something big and something like a mountain [yeah] it is a little bit similar with what I have done before, but I think something like [it's ok you can also borrow ideas from the previous one] ok, yeah hmmm, maybe but this one is perfect, but the thing is its not stable enough to stand, stand how to

say vertically [yeah] so maybe this one, but this one is a little bit small, and ummm, …put the two together…so the two together...yeah maybe the two together will be good to put in here, and also here. Yeah because in China you know there is like it resemble some, something like a goal or a mountain is a goal, or something, a mountain resemble once you reach something, they will describe some very tricky problem like to climb a mountain, so when people see this its like a, the peak of the mountain [yeah] so they will have meaning, that they finally see something I guess [yeah] so yeah this is pretty much for this, first they have to go like this and they will explore until they go here and they can see this like their goal achived, it is such a meaning [that's really nice, I think its right on time], but its, it's really not Japanese garden [its ok, the focus is on the composition] ah, composition [so…].

A.2.4

{1st composition} Ok, ummm yeah let's see, this is, oh actually I will try to make something, something that reminds me of a, how do you say, this big lake, in Siberia called "Baikal" lake. And they have this island, and there is like a really famous touristic spot "Shaman Stone" which is actually just like a big stone, I don't know like a rock going into the lake from the beach, so I'm not sure [oh that's nice] so I'm not sure if I can make something similar, but let's try. Maybe it's like….this one, and just looking my head, and they have this thing, it has some, some…something to do with the local tribes culture of, hmmm magical stuff you know, like [yeah] Indians, so they think its kind of a sacred place…[if it doesn't stand well we can also support it with something in the back] the thing is maybe it should like some engineering in it [laughing][it's ok]. This actually…maybe I should have a look at the picture first but [that's ok, I will ask for the picture later] I'm not sure about the original [laughing]. Maybe, yeah but maybe its gonna be a little bit different from the, of course, original terrain let's say [yeah] but it should remind, should remind something. This is something that….so they have this stone, and they have like a, like a spine like going to the spiral movement [yeah, ahhh] going to the shore, so lets see, here we have….how many stones actually? [that's ok, don't worry about that for now] so I think it should go like [ahhh like this kind of line that goes] yes yes yes. And I think….yeah maybe its gonna be one with…[hmmm, where is the shore in your design?] shore let's say…[I mean in the front?] yeah let's say this is the shore line [got it]. Yeah and I think, it will be, so it has something like hmmm, something like…maybe not…something like a small, like let's say bay or something [yeah, ahhh so the water is around here, if I understand correctly] yes yes, water actually comes around [around the whole thing] so the whole thing is like, there is like a bridge, and here is the island made of like rocks, going like this way, kind of look like a…look like a maybe, like a kind of dragon [yeah] lies and put his head on the shore, and his back spine with all these sharp [spikes] comes out, and I think maybe it's a little bit like, it's a little bit ahhh, there's like a curved

line [aha] maybe we should emphasize it more…like this…[hmmm] yeah I think…[I can really feel the movement] yeah more or less I think it looks like this [oh that's nice, I really want to have the picture later, its not so important that's its one to one, but the idea is the important thing] but yeah this stone somehow reminds me of this place actually. [so I just have a question – if there is a reason you chose these ones for here?] ahhh, I think I was thinking about the shore so I took one with the plain, more or less plain surface they have [ahhh, ok that's nice] and for the expression of…like lets say this is the horizontal expression, and now were starting to go more and more to the vertical expression, which is actually this kind of rocks, so from the shore [yeah, so like transferring from the horizontal to vertical] yeah from horizontal to vertical, we start using these stones, also putting them…lets say the orientation of the stones may be differently [yeah] and I think they're kind of, this sharp, I actually like this, the first stone, the biggest one, I think he brought the idea kind of first, but of course, like those stones they're more, their concentration they're more dense there [yeah yeah yeah] so just trying to simulate the, the ummm, the distribution of the stones here [that's really interesting I have to say, because you are the fourth person who really likes this one] yeah? [yeah] [laughing] maybe it's a [something special to it] designer's stone…how do you say like the first, they say like touch stone, something they start the idea from [yeah extactly] there should be something you start the idea from, and maybe because of his shape, lets say like…he's the leader [yeah I think so too, it has kind of like an expressive shape, yeah yeah yeah] and I yeah, and somehow he actually hmmm, I think he has this shape that somehow brought the idea of "Shaman Stone" or whatever [that's nice, so do you mind if we clean and did another one?] ok, yeah I was like thinking what should we start the first design with [yeah actually…] this is the most difficult [yeah exactly, the beginning is really hard, because once you have something you can always improve] but you need to have something to start with [yeah yeah yeah which is…] should we put them back? We don't have to use the same with the next one right? [no no no completely free, let's smooth this a bit, doesn't have to be so clean…ok, yeah, by the way, you can also make something without a theme, just shapes that you like that's also ok, or whatever just…] abstract? [yeah that's also good].

{2nd composition, 9:51} So…let's try to make maybe, something like Stonehenge [oh that could be interesting]. I don't remember actually how this, how the Stonehenge looks like, I think it's just a, I think it's just a…columns [I think its two halves of columns, like two halves of a circle I think] yeah [not a full circle right] yeah, it's kind of, yeah it's like kinda look like a circle with those stones [oh by the way, there is one rule, the stones should be on the ground] Ohhh really? [yeah I'm sorry I didn't mention that]. Ok then we will maybe not go with the stonehenge topic buy try to do like random...[so right now you're just exploring?] yeah [that's ok, it looks interesting]. Maybe, maybe I can, maybe its like you know, I went to Okinawa in summer [oh] and there was, there were all kinds of rocks, and they create kind of, ummm, not a labyrinth, but interesting routes [yeah] then you just walk among the stones and maybe

you can walk inside of the kind of a cave which was [how big are they, the stones in Okinawa? Is it like man-sized?] yeah or they kind of, much higher [wow ok, that's interesting] so and actually they create different interesting…ummm, I think because of the…when the sea comes up to shore, and they are kind of washed, and the surface of the stone, like the vertical surface of the stones, kind of has this interesting, a lot of cavities in there, so its kind of like washed by a…by a sea…[ahhh] by the water. And then when the water comes back…and then those really…kind of…then it creates, so actually its like a natural hmmm, natural like physical phenomena [yeah] which water just comes and goes back, but it creates kind of space, so the sea and the stones work all together to create a kind of a space, architect, lets say like a "stone architecture" but it becomes like, maybe there is…of course there is no intention to create this kind of space, it just comes naturally I don't know, so in a way I think it's the same as we do now, so we don't have any particular design to create, just putting up the stones, and It… and it just a…take the shape, appears naturally kind of, ok that's the shape it takes suddenly [yeah] let's say spontaneously, spontaneous composition. Yeah maybe there like, there is cavity like this somewhere [this area looks interesting] yeah so it looks like a gate [yeah] actually we have two gates, here and here. So…and then maybe… like an entrance… yeah maybe [so we have like another minute or two, so I just wanted to ask if you can talk a bit about how this is similar or different than what you saw in Okinawa, like if you find some similarities or differences from what you remember?]. Oh, I think the first is, of course all stones there they're kind of like a solid, so they look…its actually one piece of land which just washed away, it's how to say…[ahhh] it's just like have this [carved through?] yeah carved through the pieces of land, and create all these [yeah] corridors and narrow spaces. But sometimes [I'll actually send the picture later also, how it looks like] and sometimes it just has this passage through this kind of, yeah, these carved walls and it looks like a cave [yeah] and there in the end you actually enter the sea [yeah] and…and sometimes it has like, like one stone, like one stone another stone…different stones, so you have…it goes like [yeah like a route] like a…yeah curved line, so you don't have…sometimes you can see straight through the corridor, sometimes you actually see only the turn, after the stones, so you're kind of curious what is behind the stones, so you go there, and there is another labyrinth, so you go there…[wow] and you go go go, and when you enter sea, so its kind of interesting, creates an interesting quest kind of, and its really, ummm, its kind of calling you to go inside and explore the area, so yeah and I think of the surface of how these walls are created, because there are lots of crabs living in these small cavities [yeah, wow] so every time you walk its like…actually they're pretty fast [yeah yeah yeah, its hard to see] they rush across the stones, yeah. And I think I have seen a lot of these, kind of stones, and they're all quite interesting, because once you walk through, through one of these kinds of gates they come out, and then you see like the white sand beach suddenly opens up, the blue sea and then you're "wow, like this is a cool scenery", you go another cavity and then you come out and there is completely different scenery, like also sea but a little bit different, more like

stones in the water, so they [so you get different views from each point in the labyrinth] yeah, so this is kind like you have this portal like kind of this [uhu] sometimes you have to climb a bit and it looks like, it looks maybe more like, like a something remains of a former castle or something, it has really a kind of, maybe like stair-look-like terrain, then you have to climb up and then you come on one of the balconies, or the place where they used to guard the castle [yeah] from outside visitors. Yeah so, I think, but all this of course is made by just, how do they call that in English [tide, or…?] tide, yeah I think [like when the water goes high] yeah yeah like flood, flooding. And I think because of the waves it's just like washed [yeah wears down the rocks then…that's quite amazing]. Yeah we…I saw this place at a local beach when with the girlfriend, and we said like yeah with have this interesting thing right here just a couple minutes from the hotel [yeah! Just go…it amazing]. So there was really interesting things to explore hmmm, yeah I think and yeah of course the difference is like, that its not that super-dense because…[the original one or…?] yeah the original one I think here it was more like here it's already the soil, like the solid [yeah] plateau [yeah] and here there more like random piece of rocks [ah all kinds of heights and…] yeah so this, how this solid piece of land start losing its, let's say, territories, going back to see [ahhh]. Hmmm [wow, so that's interesting because in your design I think the largest similarity is probably the negative space, right? Like if you compare this with the Okinawa place, so the things we don't see like the routes, are actually the…] ahhh yeah maybe, because like you see the overall picture and maybe you can create the…but actually we started with the Stonehenge [ah, that's true, there's still a memory over here yeah, but then the conditions changed [I'm sorry for that…] [laughing] and then I had to switch to Okinawa…[oh that was awesome].

A.2.5

{1st composition} I choose this, because it's very big compared to the other...[ahhh, yes you saw it immediately when you looked] yes yes. And then I want to put it in the center [hmm] and uhhh [yeah] it means quiet, and outstanding [hmm]. And I want to make some small stones [yeah] maybe not this kind [yeah] because its close [yeah] so I want to use smaller [ahhh, can you show this one to the camera, yeah not this kind] not this kind [ok] or this kind [hmmm] it must be smaller in my opinion, yeah and it can be compared to the big one [ahhh]. Maybe a center island Is a kind of the image [yeah]. A big island in the center and a small island [ahhh] yeah something like that [so we have a big island and a small…on the side] yes. Maybe a kind of Chinese, you know, Chinese traditional painting [yeah] we have a title [yeah] and the other things are for…[ahhh there is a main element] yeah, and small elements [ohhh] something like that. A big one, a small one. Maybe there is one smaller than this kind, maybe like this [yeah] and I put it in the other direction. Actually, I want to make balance [yeah balance] of the whole, maybe two, maybe one is not enough [yeah] maybe two like this. And

it cannot be in the center, a little bit [ahhh a little bit asymmetrical, to the side] to the side, a kind of moving [hmmm]…like that, and this kind, so I try to make some change because of my feeling of balance, I want to get a good sense of balance [yeah…so while you do it you try to feel] yes, its beautiful or…[hmm] a kind of moving but balanced [yeah, ah something in the middle, not moving…not completely moving or not static] yes [but also balanced] yes. So in my imagination about…you know in the sea [yeah] ocean [hmmm] and island [so this is the sea, on the white] and these are the islands] yes, yes. Maybe, maybe this side is too flat [yeah], its not…like, its not natural, maybe this side is more natural [ahhh, yeah its true, this side has more like broken places, and you can see its less perfect]. Yes, and…and this kind of stones has many angles [yeah] I want to put a more flat one [yeah] something like that…its not…it cannot be too much [ahhh like too many…] yeah like too many, but not so less [yeah, yeah if its too little then it feels empty] yes. Maybe this is one composition [good, its exactly on time, lets clean?]. And…shall I do the seconds one [yes, that was nice], and don't worry I'm filming everything so I will recreate the compositions later using the top camera. Let's clean for you…ok]

{2nd composition, 5:43} I think the second option, I will use another, another aspect [yeah] so I will forget this first [yeah, ahhh ok] and take the…you know, maybe not smallest but…[yeah] in the middle, the size is in the middle, maybe this one [yeah] and this one also cannot be in the center but…one side [yeah] and maybe can control the area [hmmm], its just a center of this area [yeah] and…the small center will have smaller piece [ahhh, around] around yes. So maybe from my imagination [yes] you know the…the last design has one center, but this one has several center [ahhh a few center like here center there center] yes yes, so I will…want to get the first center here, yeah this is the first center [ok]. Maybe the bigger ones will be close to the [ahhh ok we go from big to small] yeah. And the…because I want to…it cannot be in the…the second center cannot be in that corner, or this corner [ahhh, it will look weird] yes. So more naturally its like this. And the second center…smaller stones [yes] maybe the smaller, actually I need one more the small [yeah] stones. But its ok [yeah yeah, ahhh] maybe I make some changes from this….[ahhh you changed the rocks…laughing..] yes [that's nice!] yeah yeah, naturally…maybe connect it to this, to…to the center [ahhh, so there is one center and one center, and they're connected somehow] yes, and uh….in order to get balance maybe put some here. Its like a…you know, they're moving [ahhh, there is like a sense of movement like this…right?] yes [ohhh]. Need to think…and this one, maybe a little bit in a…from here [ahhhh] because he has a good control over all the plan [yeah]. And…you know in China we also use a dragon [ahhh] and fireball [laughing]. I think this is perfect, for…yeah [its nice!], for Chinese you know it's a…[it's nice, ok its exactly on time also. So we can clean and do the third one, third and last].

{3rd composition, 10:14} I think for the third one I will use the big stone again [the big stone, ok the one from the beginning?]. Maybe the third one is a big center in the center [yeah] and not exactly in the center but, but we also...I also used the sides, like this together with it [yeah] and becoming smaller and smaller, maybe this is the third concept [ohhh so there is one big center…and everything becomes smaller and smaller] smaller and smaller. Maybe this is the third conception, its simpler but…compared to the to [ahhh, yeah I understand] yes, its simpler but…[but its ok, simple could be good] yes, becoming smaller and smaller…but you can feel its still moving [yeah…]. Even though its simple, we can do several changes like hmmm, something like that [hmmm, how did you decide where to put these, for example?] hmmm, the feeling of balance [hmmm] so I must take it as the center of this area [yeah] and becoming smaller and smaller [ahhh, from that one…] from that one and….yeah, I don't want to, you know suddenly become this [yeah, ahhhhh], like this. Becoming small…[I understand, so this is bigger than this one, this is bigger than maybe this one for example, so it becomes smaller and smaller]. Yes, maybe it can be two centers, from here to here [ahhhh, so there is one center here, one center here] yeah [these ones are around this one…] but this center is smaller than this [right…weaker] yeah [weaker in comparison]. Maybe the stone…this side should be bigger, the stones [yeah…ahhhh] yeah. Bigger and smaller, yeah…[oh nice] this one Ok, the third one is…also two centers but bigger and smaller [ahhh, ok so we have like…its similar to the previous one but different] yes [the previous one looks like two big centers…] yes [and there is some connection between them. Here we have this center this center, this is big this is small, and they're kind of blending] yes yes [hmmm] yeah. [for you, this rock belongs to this one or this one?] hmmm [maybe both…I don't know] both…[both right? kind of…] a kind of direction…[ahhh] maybe this side is bigger than this [ahhh we can put it on the big side [wow, nice and right on time] OK? [yeah more than OK, perfect! Thanks a lot].

A.2.6

{1st composition} [ok we can start] Ok, so thank you Yuval for inviting me for a little game [thanks for coming!]. So I might have some misconception because I know a little bit about rock gardens but I've never done one before, perhaps that would be…[yeah, that's completely ok, by the way some people have made a Chinese style or Japanese or even broke the rules and made something new that doesn't exist so that's also ok]. How many rocks I can put here is there a limit? [ahh basically no but beyond 15 is getting like too much] but more than 1 I mean more than 0 [*laughing* yeah more than 0. Maybe in the future we could have just patterns in the sand that's also something]. So yeah, let's see which rock looks the best, ummm. I hope I'm not recreating anything existing [there's so many options so you can be calm…]. Is it better to try, or is it better to have some concept? [you can do it freely if you

want you can just go, and then even re-design it or change that's also completely fine]. What I would I would try a few first, and then see which one I like. [Yeah why not. So right now you're comparing this one with this one]. Yes, because I'm trying to see if this one matches, because I would put this one probably near to this one [ahh I get it]. Hmmm, i'll probably want to put my bigger ones first [ah start from big to small, yeah]. Then somehow I want to have three *inaudible* because I want to have some balance, because two seems a bit empty [yeah, I know what you mean, actually some people have said that]. [Can I ask what made you pick this one and this one?] Hmmm, I picked that one because I want something tall in the back [aha] and I picked this one because its relatively large so I want that to be kind of balancing on the right side, balancing on the left side, and this more like a foreground piece [yeah]. Hmmm, doesn't seem to fit really well though [yeah]. Which side is front which side is backward? Does it matter? [in this case it doesn't matter, although you know in the traditional garden] it has to be one way [yeah yeah, if you place it upside down, the owner of the house might die] that doesn't look…yeah it seems like there's some typology, like some of them match better together I feel, so perhaps that it one way to group them first [do you think they match because of the color?] I think texture and shape. [texture and shape?]. Yeah, probably. That might make it easier to choose. [oh that's nice you're organizing the rocks in groups]. Because I find it…yeah, there's too much information. So I'm doing like testing. [yeah] Some kind of visualization on this [yeah that's nice]. Closer to here, this is probably closer to here [I might take a picture of this while you do it] So it seems like there is some grouping [yeah, that's quite a clever idea I have to say, nobody has done that] *laughing* clustering first. [clustering, yeah because it's really hard to deal with the complexity, I think so too]. I'm very method-base as you can see [so you look for the method on how to perform the task?] yeah. This might be a bit big [yeah]. I'm looking at it from a lower angle, to create maybe some kind of space, in a miniature way [ahh so you imaging the rocks to create some full size scale space] yeah, in the beginning I weren't [yeah] but then now I think maybe I'll try that [Ok, in what moment do you think you started to think like that, can you spot that minute that you transferred from just working to thinking about] human scale, yeah…maybe when I picked this rock up, it kinda made sense that kinda looked like something, because there's this shape and that' shape [yeah] so there's something I find it unique, and then it made me think about going down into that scale. [ah, so because the kind of fit] yeah yeah! [so that made of focus on that?] yeah [hmmm, that's interesting, because it also caught my eye] yes [this face and this face they kind of want to be close] yeah, and that kind of made me think "maybe one way to do it is to…". [hmm, its also interesting to look at this scale, and from this angle] because in the rock garden you would probably be sitting here, right? [yeah] and then you would be looking this way. [yeah] well, one of them, but there's probably other ones when you walk around, here there, but I guess one of the main views would be you be sitting at this angle and looking this way, so probably this view is important. [yeah its quite popular to make the central view as the sitting point in the center] hmm [yeah sometimes

they plan a few good ones, and then they will place like strategic viewpoints, yeah. But like examining it from here I think it's very important]. Do you think they're too far apart? What do you think? [this cluster and this one?] yeah [actually a bit] yeah [in my opinion]. But its going in an interesting direction, yeah]. Seems to be like, interestingly, there are some coupling between these three clusters, and they seem to talk with each other. I don't know [ahh, I can see that now, after you said it. There is some like, it looks like its leaning towards the other one] yeah [and also maybe in this case…]. Somehow, is there like a a fourth cluster, or change that cluster…[ahh, deliberating whether to add one, or just change the existing one?] yeah. Should I use this view, or should I use my own view? [ahh you can choose, but if you have a view that you think this should be viewed from, so later I will also take a picture from that view] Ok. [It's interesting to see it through the camera also, it gives you kind of an overview] yes. Do you think they talk with each other, the clusters at the moment? [somehow I see a connection, because for me, I see this kind of pattern repeating, that they have a stripe between them in all three cases, and here it doesn't happen…] hmmm [its quite interesting]. Yeah for me rock garden is always about the empty space [ahhh] that's how I always see rock garden. But I didn't look at…yeah I don't know it's just when I go to one, the thing that really caught my eye is the emptiness [actually it's a very good point, you know] yeah [because the amount of emptiness] is important [and its huge, in precentages if you measure like how much nothing there is there *laughing*] yeah. And actually its…the reason the rocks are there is to make the emptiness stand out [Its true if the rocks are not there the space is just..] the space is more important than the…but you need it to structure the space. That's how I feel rock garden should…I feel rock garden are nice in that sense because it brings you to kind of another experiential space altogether [yeah] that's what I think is interesting. And that's why I see it somewhat similar to art [yeah] it kind of brings you to this other dimension [yeah] so that's why I think the empty space is maybe the main character. That's why maybe I'm just shaping rocks to make sure that it looks nice but at the same time make sure that there's spaces between them [yeah, there is always tension in the garden between this and this, because they always like to use a lot of overlaps between the rocks, but it doesn't mean the rocks have to overlap. This idea of creating the tension between them is really interesting I think]. Hmmm, maybe its too dense here [yeah. For me what's very interesting is that even though this one is very different from most of them in the color – its kinda yellow, still somehow it fits]. Yeah this is the one that is very different at the moment. [ahhh this one?] yeah, these two, if you look at it this is a darker one, this is similar darkness, so maybe arranging like this also influence my design [ahhh, like the categorization you did?] yeah, if I didn't have categorization maybe I wouldn't think like this, I don't know. Just more experimenting now [yeah why not, let's see all kinds of options]. [it's also interesting to look from the top. That's the only way in real life to get a top view on a rock garden]. Yeah, that's why its probably better, much better to work from here [yeah but it's also nice to look from there if we can…]. You know in ikebana they design from all four

sides, I wonder if they do that in rock gardens as well [I'm sure they do] so that you get a good view from this side, this side, that side and that side [yeah, well in the rock garden it's not a golden rule but usually there is at least one wall behind]. Yes it would be nice to have like a wall, or maybe some trees or something [usually the wall is kind of here, or a corner. Sometimes there is a, like a floating garden, you can walk all around and there are no walls. But usually, they design the rock garden as to let you have a few good views from the balcony, so its called "engawa" like the outdoor. Its kind of like a connection between the outdoor and indoor in the Japanese architecture, so you sit there and they will design a few good views for you]. I'm just trying…[yeah why not]. [can I ask which part do you like the best here?] at the moment this [yeah] that's why I'm definitely not changing this, because I like it, I like the shape how these two are. I quite like this one because it's the first one I chose [yeah] I don't know why, I like the shape of it [the shape is attractive like when you saw it you wanted to…] yeah I wanted to use it. Yeah I like the low profile of these ones, but their colors somehow don't really match so well [ahhh] so there is something about this that is not really working, but the shapes kind of match [I agree about that] the shape is kind of ok, but in terms of the color maybe these ummm [yeah it's hard to find a good match in all cases] yeah [although it is true that usually in the garden the colors match, usually not always, but they try to not let one element stand out]. So ok just flip it, oh I don't know [well it could happen. You are trying to recreate the same structure, or a similar structure using different rocks, right?] Maybe this one is better too…I don't know. Can I try two options? [definitely]. So I'm just reducing, I'm just trying to work with two rocks first [yeah] because…and I see if it fits [so you're working two at a time?] yeah [and then trying to fit a couple, somehow…] yeah [by color or also by the shape, or maybe both] yeah. I feel that, that has to be the highest [the back one?] yeah, and these two probably are lower, and then you have something in between these two here. I'm really, I'm going free-flow at the moment [no problem]. I fell this time I probably want to use the darker colors, so that its more "one family" [yeah, they feel uniform] yeah. I forgot what I did earlier [that's ok you can fit it as you feel now]. [So can you try to explain why did you add this one? Maybe its hard but…] yeah I'm not sure. I don't think it really works, I was just trying to see if these three can be a cluster, but it seems like they don't look so good when its together [ahhh, yeah somehow, they cannot fit as a group] yeah. So that's why I was experimenting with it, because it has a similar color, and its pointy. Because some of them it doesn't match, the ones I notice is for example this one is too smooth, and the too smooth one doesn't really match the…[the contrast is too big I think] yeah, I don't think round rocks work really well, I don't know why [agree] I think its just, its too soft [I think so too, actually they're not to my personal taste, and they're less common I think, but…in this kind of design]. Its more difficult than I thought, actually, because its so free! There no like, constraints…[yeah] the only constraint…the only thing I had in mind is like I want to make a garden that can at least, at minimum achieve a similar feeling that I had, when I go to rock gardens. [hmmm, that's your basic…] yeah baseline [but I think it's quite

an interesting result] I'm just thinking should I add a third…a fourth [no problem, that's ok if you want to experiment…] the balance is now…[yeah now I'm thinking that maybe the reason that the third one didn't fit here] yeah [because these make kind of like a closed shape so they want to stick together] yeah [but then you put the third one and it looks like it doesn't belong]. Yeah the kind of spacing thing is not here anymore as much [yeah, but you have a few very good combinations I think. These ones, these two and these two are like perfect match I feel] yeah they somehow, they go together. [you don't have to hurry, but we're past 30 minutes] ah ok [so whenever you want like a…] I'm almost done [sure, when you feel its ready]. [time flies…] yes I didn't realize, *inaudible*. Let's have a view like this [yeah] where do you think I can improve [first of all I think it's really really interesting. Like I didn't want to affect you too much, but these two they complete each other, kind of makes me feel like mount Fuji you know] *laughing* [and also these two, even though they don't have the space between them, there is still space here that's created, and that really helps me to imagine, like it's a miniature. You know there could be a small person there or something…and this opens like the…at least for me the imagination to all kind of things that this could be, doesn't have to be a stone garden] I was thinking more like, yeah, should I do like a miniature? That's one option. The other option I was thinking maybe is to create more, more like abstract art [yeah] I was thinking which way to go. But it seems like when you touch the rocks is seems makes more sense to be a miniature [yeah, it's a very common theme in the gardens, to represent a miniature world, idealized world. Somehow it's very tempting to do that] because, its part also the tools, is this how they also designed in the past? [I don't think so, what is very common, maybe they also did this to make it easier, but what they usually do is they go to the outdoors to collect the rocks, you know to the quarry or whatever place they collect them, and then they will observe and spot a few good ones that they like for some reason, in the same way that you liked this one, and then they will organize them in the quarry] ahhhh [like it was the garden] really? Wow [that's very common, there are all kinds of method, but that's also something they do. I guess working with a model has ups and downs] yes [upsides and downsides. But I think you're right - the fact that that this is a miniature of the garden makes us think of this context] yeah definitely [yeah]. I chose the darker color ones, because I think it contrasts better with the white sand, the whitish sand, I don't know [ahhh, yeah that's an interesting point] where would you improve [so for me I would usually prefer not to keep this kind of closed shape, or suggest a closed shape like a loop] ah ok [before, when you had two rocks here, that was very prominent, and for me it kind of bothered me, because it felt] too much [maybe a bit artificial] ok [and usually, if you want to resemble the real garden, they try to make it looks like not-artificial, although obviously it is extremely artificial, yeah so they refrain from…] symmetry [yeah, this is one thing. So sometimes when we recognize symmetry we could break it] break the symmetry [yeah somehow. Ummm, if had to conduct any change, I might have taken this one somewhere over here but I think you design is interesting at many levels. First of all there are all kinds of good matches here, like I said

before, but also you created this kind of concept in your design, ummm which is "try to match one rock with the other", and then you used that or applied that on different clusters. But still even though you have like a unifying concept, every one of them is unique, so I think its special] thank you [yeah I really do]. [And that's exactly why I'm doing these experiments, because the goal is to see what kind of way of thinking that human have that machines cannot do] many [yeah many, and you discovered this by doing this because even here you know, like when you let the machine design something, it usually doesn't come up with a concept on how to design] yeah it's true [it just follows some principles] rules [yeah yeah, but when can do this very naturally right? you never did a garden design before?] no no no [but you did use principles that you know from design and somehow you managed to do this even though you never touched this]. [oh and one more thing I didn't want to say before, but many people like this one, yeah its quite amazing almost everybody] really? [in the previous session I let people design three short composition, and this one was selected every time, at least in one session per person] it's a beautiful shape [I have to admit, yeah. It attracts the eye very fast, the shape is very expressive, I think. Even by itself it could be a composition] yes. Maybe even just that and maybe one more rock, that could be something, more minimalist [yeah]. [it's always hard to decide whether to add or to remove] yeah its really difficult, its more difficult than I thought. [its definitely difficult] its difficult, because there are not many elements, so you know every element has a very large impact] yeah [its not like a window in a building…] I guess like one thing..like doing it once I guess one thing now learning from this experience, maybe like I can design smaller areas in one time, maybe just this half [yeah] and see if this half works first, and then design this half and see if it works [yeah] and see them all together, or also maybe within here first, and then here, and then here here, and then together [ahh, that's an interesting strategy, you mean focus on one area, design something there without noticing the rest] yeah trying to reduce the informations of too many options [yeah] I'm surprised how many options there could be [yeah it get complex very fast] yeah [almost, how do you call it? Combinatorial explosion] yeah, yes yes, really really quickly [because anything you change creates many many effects on the whole design] yeah, I'm really really surprised how even just one shift can has an effect [it's true] like just a slight shift [slight shift to every direction and suddenly…] the feeling changes [and then you have to adjust it somehow, but the problem is when you adjust it you create more changes] yeah [so you always have to keep this balance and try to feel…] yeah [that's interesting I think. Yeah try to feel if the changes are going in a good or bad direction] now maybe it's too dense, I don't know. Either here or here, I'm ok [yeah, some people actually fill the whole tray with rocks. Like they almost used everything. I think that's really hard to control, ahh but sometimes it's possible to even do that, although I must admit I am a minimalist] yes. I really think the space is so important in the rock garden. For me its really about the sand, or the small white rocks [yeah yeah the gravel…] the gravel is really the main thing for me [I think so too] and it seems like these are the minor characters compared to the white sand, because

without it, it wouldn't work, it would fall apart [I think so, yeah it's kind of like a unifying factor] yeah it could be moss, it could be rock, gravels, but yeah it has to have something, like a really important surface. [yeah, actually the first time when I went to this kind of garden so I thought "wow this is so amazing", because you know, you can never find places in the world where there's so much empty space, with white on the floor, and you cannot even step inside so it makes you feel like "wow, there is so much respect to this patch of…"] space, yeah. Space is first I think in rock garden. [yeah. Wow, could you give it a title maybe? Sometimes I give my compositions a title just to stick the…I don't know whatever image I have in my mind to the composition. Well you don't have to, but if you have any title you think is suitable that's good also]. Last rock, and finishing, I probably took too long. [No that's completely ok. Like the minimum of the 30 minutes is to be able to produce a meaningful design. But if you take more time, that's also ok]. [What are you thinking about?] two things: I was thinking about the name [yeah] and I think this one, probably doesn't…because I know like rock garden is kind of like water and then mountains in the back, or islands, but I feel this is like a maybe…a name is "above the clouds" [ahhh, wow. That's nice...] I don't know, because I feel like, its above the clouds [that's nice, that's a pretty powerful name. It's true, the theme of water is…] common [highly common, it's almost everywhere, but…sometimes they also have multiple meanings] yes [so it could definitely be above the clouds]. I particularly like this view [this one? From the right?] yeah from here [I will come over]. It's less minimal [oh this view is very nice, I will take a few photos from here, but I also like the view from here, because here you can see the empty space, which for me it's very interesting, it's like a cave you know?] yes [under that one]. [wow but the change in perspective can really change…] yeah now I see that I'm seeing that it's a little bit imbalanced from this side, from that side it feels more balanced. [yeah it's always paradoxical because we always try to control all views at the same time] but it's hard, it's not possible right [yeah, maybe after many many adjustment we could get at a satisfactory level let's say. Yeah but whatever we change we break something in the other view].

A.2.7

{1st composition} So now I am looking at each rock individually but I'm not making a selection yet [ok], I'm just going to…where did you get these rocks by the way? [I collected them by walking outside and trying to find all kind of shapes to make a variety, yeah my wife picked some of them]. Ok, I will not guess which one did you wife pick [*laughing*... I can tell you later, I don't want to affect you]. Ok, so the first rock I'm taking this one, and the only reason is that it reminds me of something I cannot remember right now [oh] *laughing*, Ok? [that's nice]. And of course I am not tempted to put it in the center because I have always been told by years of design, "don't put anything symmetrically" [ahhh, it's like a rule of thumb] yes,

rule of thumb, like "oh no don't put it in the center", but of course if you want you break rules you put it in the center like "yeah", but I have been, I have been damaged by teachers [yeah yeah yeah, we cannot get rid of this] right? [yeah]. Because now I am tempted to put something in the exact opposite, but I will not. Why? [resist this temptation…] I am resisting this temptation now, and I am also…the lone rock over there, it kind of reminds me, I don't want to say it but kind of like cat feces in the middle of the sidewalk [ok *laughing*] so now I want to resist, I want to make it go up now, I feel this like, I want something to go up, and not be so horizontal, like rounded, so but no now I don't like it… in fact I'm not liking this choice at all [the first one?] the first one. So do I…[when you thought about making the vertical one, so it was in contrast to the horizontal?] yeah [Ok]. But now I'm like, huh…like I want little islands to come [yeah] but again I don't want to take this one because that's like really huge, and I feel like its dominating everything around it, so that's why I'm not taking that. [yeah] but I also want variety in size, so even though these guys are kind of dissimilar in size, so I'm just wondering if I should take something smaller…maybe it's a little bit further away…or do I make these look really big by putting something else by putting something which looks like a big rock [ahhh] but..,I'm not sure. [it's good to try] its good to try. Or maybe something like a different color? This is coming in front…but that's ok [maybe we need more sand…] that's ok [by the way, if something doesn't stand you can take a small one then put it behind, its ok its not seen by the camera] but aren't we being…*points to to camera*…big brother is watching us! [that's true] *laughing* [but actually this one it to enable to reproduce it later] ahhh ok. [yeah]. Kill your darlings, that's another thing, kill your darlings! If you're too like, attached to one thing…no I hate that. These are just rocks! And I'm being so "no I don't like this rock" my gosh. [just rocks, but they have some features…] just rocks, I'm like oh my god I don't like this rock, I don't like that rock. Human beings are stupid! Why am I thinking so much about rocks? [*laughing*] stupid humans. [maybe it's because were smart…]….like overthinking, like now I'm looking at this – is that aesthetically appealing for me? No that's not. But wait…[youre not overthinking, that's completely fine, yeah you can go like the whole half just deliberating that's also ok]. I like this rock, I don't like that rock, wow! Now we don't have any of the original rocks. [so I just want to ask like in the meantime, when you said "I want to make islands" so where did that come from?] hmmm, I think recently I have been trying to book a vacation to islands *laughing* [ohhh] and I'm like that's what's on my mind, because everyone in my lab right now has gone on a vacation except me, because I don't have money and...life, right? [yeah, student life] student life. Everyone's in Thailand, or Okinawa, somewhere I'm not, and I'm like "what the fudge guys, what the fudge?", maybe that's like the thing. [wow, so you have this kind of association] yeah like I want to be on an island which is not Japan. [yeah *laughing*] lives are complicated [it's nice, it's nice. Many people have this idea of island or this concept of island when they make the design, but every person has his different story, so I always ask]. Why is everyone into islands? [so sometimes its just because they saw a lot of

Japanese gardens] ahhhh [and they're thinking about the real garden, you know]. I think that's the first thing which comes to mind, even you showed me in your research that you analyzed that. [it's true, I think the most iconic, maybe design style or something is…] design style…it was bugging me. No, that I hate *laughing*. Wow it kind of shows you how we have been conditioned by the media, to be just thinking about, these things…[what, like about the aesthetic part all the time?] yeah, like not the aesthetics, for example, like there's a rock therefore an island [ahhhh] see so I'm like, my goodness, social media is affecting my brain to this point? [hmmm, wow if you spend a lot of time on that, it might sit in your head for a long time after] right? [so right now, you're organizing the rocks, right?] *laughing* yes I am, sorry…[no that's ok that's actually a very clever strategy, and I will take a picture while you do it] *laughing* ok, so I'm done with that now, so you can just take a picture [some people do that, you're the second person to do that] wait wait wait…you know I will take a very long time to do this now, cos' oh my god, arranging rocks is such a good idea! [that's really ok, yeah that's a good idea]. [how did you arrange in general? You don't have to go so specific but…] hmmm, that's a good question? like these two are pointing up in my opinion, these things are pointing in that direction, these seem like obviously asphalt I think…[so there are some groupings…] yeah, and these one are kind of lighter sort of shade, this guy is huge, this guy is tiny but they're kind of like pointing in the same direction. This guys is also looking up, but so is this…and then like oh pointing in that direction, in that direction…I my MIND its pointing in that direction *laughing* [I know I know, by the way – remind me to talk about that when you finish] in my mind…*laughing* [it's a very good point actually] ok look I'm going back to the original one I selected, but I'm putting it a…like just avoiding the whole, which was reminding of that very negative sort of feces on the sidewalk thing…[ohhh] that just tainted…[so we decided that didn't work completely] at all. [So we can leave that strategy aside] leave that aside [yeah]. Ok I think I'm done now [done?] *both laughing*. Ok I'm not putting more, because I feel like the rock selection that I have right now, they're very similar in size, so I want a very tall upward pointing rock, with this very grounded, small round little rock [ahhh] not completely symmetrical, like I was tempter to put this one right in the middle, because I was like "it will piss off all my teachers" but then again my natural human error thing, I think just judged distance wrong, and it put it in the side, but that's a part of the design now. And, there it is [wow, I like it, what do you think about it, like how do you evaluate it?] I think its fine, because, for my personal thing, this size of this frame, doesn't need more rocks [ahhh]. Maybe I would remove these rocks and then keep the largest one, but then again, I feel it's very dominating [ahhh if you place that one it taking all of the attention] exactly. I was kind of pretending if this was there its just going to take away everything. So that's my design decision [Ok]. Now if had a rake, I would get rid of all of these [ahhh, make it smooth?] *both laughing* it's my neurosis showing at this point [not its completely fine! Actually, that's just another level you know, another dimension, of the design that were currently ignoring] oh, of course I can imagine [because it makes it even

more complex you see its already quite complex] yeah, its very complex. [Would you mind to do another one?] not at all! I can do this all day. [Really? I would be happy if we can do like maximum 3]. Oh sure of course.

{2nd composition, 11:00} and part of me wonders if my previous design decisions were kind of influenced because over here there was this very obvious hole and my eye and hand was attracting to this pre-existing hold a lot and I was like "should I give in to that?" and I decided to give in, but that's when I was like "where is the rake?" *laughing* [wow even before you put anything there was a hole] yeah there was a hole, and that hole is telling me, its tempting me to put something in there [that's a very good point] yeah. Piss off out teachers, by sticking it in the center, hells yeah [yeah you can be free]. Again I'm experience slight problems, but I feel that the, like I understand you've done four [yeah] different scales [its true] but they're very similar, my mind, my human brain is like "they're so similar" [*laughing*] [yeah they're quite similar I think in the future there will be larger rocks also…much larger] when your machines try to take over, I get it. [I really hope they will not, they will be too busy designing]. Oh I want this to be there, oh people can see my other arm, my anonymity is compromised *both laughing* [I think nobody will care]. Ok I'm done now. [wow] That was faster than the last one. [how did you make that? That was kind of…] fast? [no, not fast but very direct] because I was already familiar with the rocks. I wasn't looking at the rocks anymore, I was like "this rock and this rock and this rock", [wow, so you felt like you can do it very freely?] yeah, and a lot of things which I wanted to do I already negated, cancelled out in the first one, so I don't wanna do that, don't wanna do that, don't wanna do that [so you looked at some rocks and you said to yourself, I don't want to take this one] yeah, like I was thinking "if I have a second chance I would take this rock", like I like the sandy one right [ahhhh] and I think that was one of the ones I picked earlier [this one?] yeah [yeah, hmmm do you have any idea, maybe its hard to tell but, why you placed it like this?] to annoy my teachers *both laughing* [not in the center of the tray but this kind of orientation] because this screen is really affecting a lot of my decisions [really?] yes because I'm looking like, cos Iv'e been trained to look at the camera – "is it nice?" [ahhh] right? so maybe next time, two advices for you: make sure that people can see this side as well [ahh like the rightmost side?] yeah both sides, maybe put it really in the corner so you can see both sides. [that's an interesting idea]. Usually when people make the design, so the maximum you can view is here, you cannot view from the back] right [hmm sometimes you can even view from the back, it exists] like does anyone get up and go around [ahhh no but some people ask me to change places. If we change places, would have take a look at this for a second] sure [and then tell me if you think of it differently?]. I actually like it more from here [like it more?] yeah [what do you see from there?]. I like that I was edging this a little bit outside from the big main rock coming out like a little surprise, but now I can see it even more so I'm very pleased with it [ohhh] maybe I should like make it a bit further away [ahh move the smaller one in the back] yes but then

I want it to…see again this thing is super affecting my decisions right now [so the angle which you consider the most is the one from the camera] exactly, because I'm one of those people [it's very good to know. Yeah in some cases, people haven't looked at the camera] at all? [yeah I mean I changed the camera, and now you can see it, but you know maybe we can do another one and I can put a post it on the camera just so you can ignore it for some time] sure why not lets see what happens! [ok lets do that].

{3rd composition, 17:00] now that we have pissed off our teachers by putting something in the center [yeah] I want to use this piece of asphalt [yeah] and I want it to have like this, like over here you can see anything, but over here you can see a lot of stuff so I put it over here, so people can see, like an I also, I think maybe this would be, I want to put it at an angle, so its going a little bit up [when you say going up you mean this part right?] yeah. Cos I think, it was sitting like here, and putting it like that I guess makes it natural, so I'm just gonna put it on the side, maybe tilt it. And then I don't know if I want the exact same color I should I use different ones [hmmm, yeah it's a hard choice, it's also hard to find the exact same color there]. Yeah, I think like in Ryōan-ji, its supposed to be the dragon coming up [yes] so I'm thinking do I want do to something like that? Do I want make a whole story about a dragon, not dragon per se but something coming out of the water like the kraken! [some kind of monster, mythological thing] exactly. [how did you remember Ryōan-ji, have you seen it?] yeah I've been there a couple of times, and I think I've associated your work for a while with Ryōan-ji, because it was one of the first things you told me about, and I was like "ah yes the person who's gonna defeat Ryōan-ji somehow" [wow *laughing* so you already came with this thought] yeah this preconceived notion about like "oh I will be making…not of course I will be making Ryōan-ji but when you wrote on your Facebook message that this involved rock I was like "hmmm" [ahh, so in your mind you were thinking…] theres a rock involved, and there's a Zen garden involved [yeah yeah yeah]. Wow human beings, weird dudes. I'm looking at the constrast between a smooth rock and a bumpy rock, and I do not like it [yeah the contrast it quite strong] yeah. And now I'm thinking that I cannot resist this anymore, what will happen if I shove it over here? Ok it not… [I think it could stand if you…nice. You want to put something?] no no that's ok. Like all architects *laughing* gravity does not let me do what I want! [yeah, yeah yeah…the physical world, you can take a small one and push it in the back that's Ok. Doesn't stand?] its ok its fine, let it act the way it wants to act, we human beings will adapt. Oh my gosh. This is also very black and white, which I enjoy [ah yeah, that's an interesting one]. And this one has little holes in it, which intrigued me, but now I'm over it [*laughing* it was very fast] *laughing* yeah. [so when you're looking for a rock now, do you know what kind of rock are you looking for?] I don't want something which is too similar in scale [aha] but now that I've just said that I've realized I used non similar scales in two of the three ones, so maybe I should go for something with a similar scale [ahhh like in comparison with the previous designs] yeah so in the previous design I know I've done

that, I know I've done that, so why not do this. Like what will happen if I used all of them which are of similar size. [yeah] and now I'm making a flower. I'm not sure if it's seen as a flower [I think from the top it's very visible] because I'm not making a dragon, but have you seen rock of flowers, or flower rocks? I that I'm just wondering "wow, lets make a flower!" [that's quite original]. Ok now, I have a particular flower in mind but I don't think its gonna happen. [what kind of flower do you have in mind?] ahh, it has three leaves that are normal sized and one which is really huge, and its pink and I don't know the name [it ok we can look later, I collect the references, if somebody remembers something interesting I collect the images later]. [when did you think about the flower? Did you notice that point?] ahhh yes, I noticed that I was talking about the dragon, its very organic a dragon, let's say it's a lizard, its organic, but its very associated with rocky things right? [yes] so another rock thing is like one of those in the desert you have a single plant which is on a rock [yeah] so I'm like "ohhh a plant, with rocks!" that's kind of weird right? [wow, well associations are like that it's very free] so what happened if we had a little tiny one instead, and we just bury it in the sand. And I can just change its size by burying it [ah that's nice you can totally do that] right? [actually, it's very common to do that] like it's too big – go inside! Ok I'm done now, oh I'm not done! Now that I can bury things, I've realized I can bury things] I mean three trials to bury something, should have done that on the first try. Did I bury you enough? Is it too far? See I'm naturally going over here, is it too far? [I know what you mean] but I'm happy with the distance this has…[when think about too far, like when you happy about the distance, do you measure in your eyes between this one and this one, or between this one and that one?] I'm measuring with the center, with the non-space over there [ahhh] these guys are around this thing, so this will also *inaudible* from here [ahhh]. And now I'm just wondering like, this is how I would say "this is too near…this would too far…" I would say that this is like…no I don't like everything going so top heavy, there's a bunch of them right over here, so maybe over here…and covered. So I feel that I'm taking the eye over here, then it comes here, which is very common in basic design [ahhh, you were thinking about how to lead the eye across the design?]. Yeah. Ok I'm done now. [That's nice]. Ahhh approval *laughing* [so if this is the flower…no all of them were nice you know…I'm just…] that is the flower, this is a fallen petal. [ahhh, ohhh. Did you come up with that immediately now?] *laughing* right now yeah. [that's quite amazing, so when you did that you didn't think about that right? You just wanted to have one more element] I was like "why am I doing this?"

{4rth composition, 25:25] [Five more minutes, I want to try and challenge you] Ok, sure! [can you try to make something with the round one?] this one? [no that one] ohhh ok sure [usually people prefer not to use it] we used this in the first one [ahhh true] not wait we used that one in the first one [oh I think it was in the front right?] this one in the front, so we haven't used this one!. I forgot my system of…its fine I know them. This guys right? why don't people use this one, is it too different you think? [I don't know…maybe they don't find friends for this

one]. Ok so this is what I would do, I would put this one here, and since I cannot judge with the screen I feel so blinded [yeah] I would do something like that, and I'm done. [wow, what made you, take the biggest one, or take this one in comparison with this one?] because I wanted to use the big one, but I was again feeling that the size is very dominant [ah you wanted to use it from before?] yeah because I feel It was the first one to touch its very each to read to and its very different so I think everyone also gravitates to that thing, and then I was like "oh but it lying horizontally would be taking up too much space so maybe we can go vertically, but then it becomes another little canvas. Now if this thing was pink or white, I would be so happy. But its not, right? its sort of like I wonder "do I want to put the white thing in front of it? But no I'm happy with the black on black. [so you mean this one is a backdrop for this one?] canvas, yeah. That is my thinking. [that's interesting, and you think that if this had a more prominent color, or something, that would create a…] even more contrast [dramatic effect?] exactly. [that you would want]. I also think that from this side [yeah] because now that is very linear and that is very spotty I'm wondering if I want to change it [ahhh] just like a line and a dot maybe [actually in my opinion its very interesting, you can see from the other one]. I wonder if that should be a little bit touching but not enough just to annoy you so close [*laughing*, they could even be touching if you want, but…hmmm] yeah. I'm happy with that. [that's nice, I think were right on time].

A.2.8

{1st composition} Take me some time to look at these rocks [sure, so you're examining these rocks] yeah. Umm, in this experiment do I need to um, consider the color and texture of the stones [ah, you can, if you want, but not necessary. It's nice if you take as many things as possible into consideration, to make a design that you are satisfied with] alright [ok]. [many options…] yes. Hmm, [so what are you thinking now, where you're looking at the canvas, or the garden, and you're looking at the rocks]. Thinking about traditional stone garden [imagining some garden you saw or…] yes, like I'm trying to find a theme for the design. Like, ummm, once I think of making a good composition in this rectangular plate [yeah] umm, for that the first image in my brain is that a corner of the plate should be heavy, and the opposite should be light. So maybe most of the stones will stay here, and there's one or two here. But then I think, this may be the theme for a scenery of a mountain, which is here, and some water like river or…[yeah] water falls down from the mountain and flow down to the river and sea right here [yeah]. Then I think that there may be some other different kind of theme like, umm, in one of the stone garden they composite a large ocean with some separated island [yeah] so there is no heavy side or light side of the plate. So yeah, I'm thinking about what is the theme for this [So for you the different things you just talked about are different styles of design? Like, one style is some rock here, one style is something in the middle. So

you see all kind of different typologies or styles and you try to choose between them before you start?]. Ah, I don't call it a style, its just a story. Like one story teller has his own style to tell the story, and he can tell a different story [go it]. After I choose the story or the theme, then I think about what the style is, more modernist or more tradition [ahhh, I get it, I get it]. But I think how you choose the story depends on what rocks you have. [yeah that's true everything is connected somehow; you cannot create some things if you don't have the proper rocks or elements] yes. When I see umm these rocks, I see that this one is much larger than others [yeah, that's true] so usually I think that this must be used for the design [yeah] but then I think maybe there's not focal point in the composition, so maybe I won't use this big one. [ah, because if you use that, it will attract the attention too much] yeah. [that's interesting…]. I think that this rock is suitable for the stone garden [yeah] because the shape of the rock has some tendency, its long on one side [yeah] and can express some movement [ahhh, I really agree]. But I don't know how to start putting this rock on the garden [have to be brave, just do it…*laughing*]. Just randomly put it somewhere [ok, that's a good strategy, to just start]. This one has a very [yeah] unique shape [ah yeah] some very clear edge [yeah, very sharp edges, you can really see the shape] can we put it upside down? [yeah why not]. *laughing*. [By the way in traditional design its forbidden, but here everything is allowed, so you can do it] *both laughing*. Oh we can make a, umm, a avendar. do you know avendar? Maybe my English is…[show me, oh avatar] oh ok, avatar. By putting all the points of the rocks on the ground [ahhh everything feels upside down] yeah. Hmm, this is a stone garden, made me think, ummm, of a situation outside the earth. [so this is like the environment in avatar, in the move?]. Ah, I remember that in the movie, the mountains are on their head and large [ahhh I haven't watched the movie I have to admit] really? [yeah, so I have to see that. Um, if you want to make it stand you can also take something and put it in the back for now. Something small just to support it, and maybe we can cover it with sand later if you want]. Just trying if it can stand, its ok because…[ok, I think we need more sand in general]. [So, just one question: when did you think of the avatar thing?] Oh, when I look at this one [ahhh, but when you placed it or before that] before that. First I think of putting it like this. [yeah] Then I think its too stable then I think if I can put it upside down. Then I see its like a, not so…how can I say [realisic] so I started to think of environment outside the earth [wow] anti-gravity [ok that's nice anti-gravity *laughing* that's nice!]. I'm thinking of making some composition [uh huh] but still I didn't decide of where to put this composition yet. [ah where to put it in the space] yes [got it] just thinking about the relationship among these three [ok, and ignoring the rest…] yes [ok]. I do this because I think that this one is tall and thin, and if I put this one like this, uhh, it doesn't…this is fat and sharp, so I'm trying to put this point…the…[they find it hard to stand…]. I think this is ok because it has some feeling of movement like this [ahhh, yes. When you sya movement, do you see like a line here or something, or you just…] I think this is the front of this stone, because it's the most pointy one, so it points to this direction [yeah] and this stone, actually the feeling is not that strong,

but I can feel this stone has *inaudible* the movement to this position [aha, so the movement continues] yes [by the way, you can also put the sand a bit around it maybe] ok [yeah that might help, let's see…umm not bad. Standing nicely]. [So why did you remove this one?] Because I want to start thinking about how this will relate with this, react with this [ahhh, so at some point you feel satisfied with this, and then you try to adjust the other rock] yes. This Is inclined so it has a feeling of outside the earth, I just don't want them to be like slipping on the ground. [I got it, so its opposite than what we expect]. Yes. [When you're doing the design now, so do you have a specific image in your mind] no *laughing* [like some image as a help or something, or just…] not really, just putting stones randomly [ok, some people think of a specific place that gives them inspiration] ohhh [but then, you don't have to do that]. I'm just trying to [yeah] like put it here to see if it can give me some new inspiration [ahhh, got it]. Or maybe, it can touch with this. Put this…this is definitely too big [too big *laughing*. Really attracting the attention]. Maybe the color of this stone gives an effect to my thinking. Now I'm just picking up stones with a similar color. [ahhh, so you try to use the color to get new ideas or something?] I just think that using a different color can introduce a different meaning to the design [ahhh that's nice. That's a nice insight] These are stones of different color, from these ones. I'm just picking out stones with clear edge and point, because I think its more suitable for the theme. Ummm, these two stand in the middle, in the beginning, because I didn't think of their position yet, so now I put them away, to rethink their position [ahhh I got it]. Hmmm, what's this? It looks like a new one. [yeah the other side of the rock is very different, it turns out]. Hmmm, this looks like a building. Maybe it's the basement of some military [*laughing* yeah it could definitely be with this shape] ok so I just treat this as a artifact. So no I'm thinking that, ahhh, this is a basement for the base for them human's spaceships, something like that [yeah yeah yeah] and it is facing some very dangerous ahhh, environment in the space, because there are many rocks in the space [ahhh got it *laughing*] and they need to go through the rocks and seek some treasure [ohhh, so the base is here?] ahh probably [ok]. This stone has similar color with others, but its shape is different, so I use this as the symbol of the treasure. [ahhh, that's nice. Yeah it is very different than all of the other one] So all need to do is to create a difficult situation for the man here. [diffuclt is like difficult to find the treasure, right?] difficult to go across to stones, yeah also difficult to find the treasure [yeah but like a dangerous environment that you have to make an effort to reach the treasure] yes. Maybe the treasure shouldn't be near the edge, because it may get less importance. And this man shouldnt be able to look through the edges of the stones, to look at the treasure, so I put some other things to block their eyesight [ahhh, yeah make it hidden]. The big stones I used to be ummm, to be the main forces to stop this human [yeah] and there are some small stones to guard the treasure closely [ahhh] I do this because I want to , how can I say…let the stones have more connection, have more interaction with this stone [ahhh, so is it like a more gradual transfer from this one to this one, like big small smaller, something like that?] yeah you can say it like that. But its hard to place these

[hard to find a good place for them…]. It's hard to balance, the…this distance and this distance [ahhh, so you feel something here, it doesn't fit?] yeah [So you keep moving it until you find a good balance…]. So these three are the, ahhh when you see the movie [yeah] the main role, first they beat some small enemy, and then they see the big enemy [ohhh] and then they make a very large effort to defeat them [yeah] and after that they succeed and find the thing they want, so these three are the big enemy [how about this one?] This is a small one *laughing*. But I'm not satisfied with the position of this [ahh, why are you not satisfied? You feel its too far…or?] its too close…ahhh before it was here so I felt its too close to the edge [yeah]. Hmmm, I think that these three is fine to be here [yeah] but I cannot see how they interact with each other, like they are totally doing their own things, they don't cooperate [ahhh, like inside the group?] yes. I think this is ok [yeah]. That was nice to replace that one, the bright one with this [yeah]. [If youre satisfied then were exactly on time] oh [yeah time passes fast right?] yes yes [I know. but if you want to continue that's ok]. Hmm. This is ummm, it's *inaudible* [yeah]. So this is one side, this is another, and this one is looking at the battle [ah just watching from outside] I think it too…its not necessary. [*laughing*]. This should be close…So this is the little enemy [yeah] right in front of the base [*laughing* yeah very close to the base…]. It should be pointing at the base, and this base…This should stop the tendency [ahhhh] so I…the whole composition, is how can I say…on this line [yeah] so on the start point or the end point of the line perpendicular to the line, to stop the tendency [ahhh got it, so everything is going in this direction and this is like the end] yes. So I think this composition is good, because it makes an empty space here, so it looks like someone would go inside here and battle with these four things [yeah] and there's some story happening. And after it goes out it faces the final boss [ahhh] and after it defeats this one it can see the treasure [wow! do you like gaming?] of course! I play games throughout my lifetime [wooow *laughing*, I think so too. This is really interesting, I liked your insight about the space that's created here] yeah I liked it too [for me, whenever there is this kind of space created in the garden, it make me feel like ahhh, it could be a miniature, you know? Like we are very small and we are here, so it makes it feel like it's a real place. Like before I was looking and I see just a tray with rocks, but after you created the space, so suddenly I can feel this is very big, and there's someone really small inside, like its easier to imagine the scale. You know what I mean?] yes yes yes. [Ok. Nice!] But maybe this went too far away from the avatar [ahhh that's ok, a big part of what we want to see is how the concept evolves, you know you start with something, and then you end with something else, so I think that's a very important aspect of the design. Like how to start with some idea or inspirations, or maybe get some idea from the rocks, or anything, and then during then design somehow this will change. So I think that's a very interesting part, so it's good it went far from the original concept!] *laughing* [wow]. I think If I had more time I could do better [you would improve more if you had more time?] hmm, including the time I picked the rocks [but that's completely ok, don't judge it too much]. I think the number of rocks here is good, because if you have too

many rocks, you will spend a lot of time looking at them [that's a good point because I was considering to add more, but I was afraid that I would confuse people if there are too many] I think you can…umm one advice is that you collect rocks with uniform or united texture and color [ahhh] because I don't think this can be put together with this [ahh I understand, a few different rocks, but with a similar color or texture] yeah [so people can choose I want this color, and then I will add this one…] yeah [so they can find a good match for some of the rocks] yes yes [I understand. That one that you picked is very unique actually, it has some organge stains and the shape is very unusual] yeah. And I think these two, once I thought they are useful because they have a bulky shape, but don't really have the clear shape. But then, I think if there are just two of them, its hard for me to make a composition [ahhh to match them with the other one. That's good feedback, thanks!].

A.2.9

{1st composition} I have to explain why this rock…[yes, why you chose them, why you placed them here, what are you imagining…anything your thinking of]. Hmmm, because these rocks look like twins *laughing* [ahhh they look alike so you chose them]. [So, what are you looking for now?] I think is is similar to a turtle, so I'm looking for the turtle's head. [ahhh]. Looks nice…[so this is the body, and this is the head of the turtle] yeah. *both laughing* it's a foot [ohhh that's nice] yeah I imagine this garden is like the sea [so everything is the sea, the white] white sea. [When did you start to think about the turtle?] this is rock is similar to a turtle [ahhh, you saw this rock and you thought it's similar to a turtle, reminds you…] yeah [ok]. These rocks, I imagine the route of turtle swimming, swim swim swim….[ahhh this is like a part of the water moving] yes [ahhhh, so its showing the direction] yes. [so for you if this is water, and this is the turtle, what is this and this? Do you have any idea or…if you didn't think about it its ok] yeah for example, the twin person, or mermaid, twin mermaid [ahhh twin mermaid, that's nice!]. [are you looking for something specific?] yeah, I want to design the…. fish in the garden [like fish swimming in the garden] yes. So I think I have to explain that [like how to show] the shape of the movement of fish [*laughing* it's not so easy, because the rocks are limited, so maybe it's hard to find a suitable shape]. This is fish [these are the fish, this one this one] yes [so for this one, this is the head?] head. [ahh that side] they're surrounding the mermaid [ahhh that's nice]. Can I shape the pattern on the sand [possible, I will not analyze it, because currently we are focusing only on the rocks, but if you want to do it to convey something, so you can do that, and I also can give you some tool to do that]. Thank you [sure]. [it's very small it's hard to handle]. [when I see the line so I feel that the turtle is also moving] yeah [so its also swimming?] yeah. This turtle makes the waves. [so everything is moving, is its just the turtle and the fish? So the mermaids they are moving or not in your imagination?] they are stopping, and looking at these swimming [ahhh so they

are static and around them everything is moving] yes [wow]. [So…so they're sitting on something?] yes [what is under them? Like if this is a mermaid what is this?] hmmm, the rock, short [ahhh like short rock?] yeah, and she sits down on this rock. [ahhh so this rock is inside the water, and that mermaid is sitting on that rock, I can see it]. [like in your imagination, one of them is more important than the other, or they are the same?] the same. It's finished. He is the visitor riding a turtle. He is a visitor. [ahhh, so this is a human being, it's a person] yes yes [and he is riding the turtle]. [When did you have this idea of this is a person?] oh, I…do you know Urashima Taro, a Japanese fairytale? [no…oh! I think I know] Urahishima Taro helped the turtle, and the turtle took Urashima Taro to a sea paradise named "…." [yeah, ahhhh so he was riding the turtle in the sea, and he helped him to go somewhere] yeah. I remembered the fairytale, in the middle [ahh like in the middle while you were doing this you thought about the fairytale?] yes. [Because of the turtle?] yes [ahhh, so do you imagine is going somewhere, like a different place, or just staying here] staying here I think [that's very nice] *both laughing*. [if we change places you can also look at it from here and see if you want to do any changes] ok [It looks different] ok, it's perfect [thanks a lot!].

A.2.10

{1st composition} So I'm going to start with the biggest one, and for good balance I'm going to put somewhere not in the middle, but not near the boundary. I'm going to put the stones into different categories [yeah] so some are dark [yeah] some are really dark [sorting them…] I'm definitely going to use this it 'cause they have a different signature, even bumps or smaller stones inside it, maybe…standing. And…so definitely something...different color. And lets start another fourth, with this bigger one. Actually I prefer the gray, I mean the cool color than the warm color so I tend to using to one with cooler color, I don't know. [Yeah. So when you do this do you have some kind of image in you head?] I think its more about balance of volume and color [ok] so that's why I start with the volume and also sort the different colors, but now I really don't know where I'm gonna put the yellow ones [ahhh] hmm, so that's a problem [by the way you don't have to use all of them] yeah but maybe I'm going to think that the yellow one would like add to something in the basic cool color pallate, but not for now. In my own opining, or in my own like aesthetic thing, so I prefer the not so bumpy and I like the slim one, and also choppy, I don't like choppy things. But sometimes choppy stones has different…[what do you think about this one?]. This one is good cause it's hmmm, why…I don't know why [yeah it's interesting, I don't know why but I like it too]. Cause when you look at mountains, they basically not look a lot like this, but a lot of them look like this, so it gives you a continuous mountain area, I guess so [yeah]. But somewhere in China you will find mountains like this [ahhh it's true I saw there are very tall mountains and sharp]

It's a specific place that they have it. Then we're gonna use this one. Yellow one…[so can I ask how did you make the connection between the rock and the mountain?] the rock and mountain? It's something really Chinese. Like if you're from China you would basically think that the stones have some connection with mountains. And in drawings of scenery you always see like there are two directions – sometimes the painter have like the drawing like this [like a vertical scroll] yes like a vertical scroll, and they hang it somewhere like in the *inaudible* but still you also have the drawing which is spread in the table and its very long, so it's a horizontal scroll. And in the two kinds of drawings you can see that mountains have different images [ahhh]. Cause in that place its really easier if you want something like this [aha] so basically you would feel that the mountain is so high and you are…you feel like someone standing under the mountain and look up [ahhh like it's giant] yeah and there are also clouds, so you can feel the distance between the audience and [yeah the viewer and…] and in the horizontal one they usually have some kind of axonometric drawings so there's no specific view, but it looks like youre experiencing the whole thing [ahh got it]. But somehow 'cos I'm very exposed to that, when I'm making this I really, I really like the horizontal one, 'cos in the garden it's more like horizontal one. [yeah, I think so too] you can go along it, so it's more like a horizontal one. So where's the boss? Where the boss it really important I think, I don't know how other people do, but to make is first to make the boss, like where the boss stands [yeah yeah, this is like the anchor for the design]. But I think the smaller piece add to their character, if you have smaller and different color of stones standing behind them or in front of them, they can feel even better, so place a leading character and then add something maybe [yeah I think that's a very important principle]. But I also want to experience, want to try with tall ones [ahhh see how it looks…] But then sometimes it's…so maybe not in the same line, it may be weird. Now it feels not so weird [yeah I think so too]. This one maybe…just try. More balance in this corner, because its too heavy now [yeah]. You can see the other, sometimes I think its too choppy so not so..[yeah we can see the ones that are left *laugh*]. I choose this one because it sharp in some edge, because when you put this one to this one, maybe somehow I just don't like choppy ones, because these things I choose usually have some edge [ahhh] and some texture. These are really like concrete feeling, so maybe I don't use the concrete group, and this one is another. OK done finished! I feel this is what I want. [ok] other things are either too choppy or…this density is good, to me. [can you change places with me, and try to look from the other side if you want to change something]. Ok. Hmmm…[you can still keep it as is. I'm interested in like…if you have some title to give to the composition or something, that would be nice too, but you don't have to. Just like, I want to understand what are you…like your image] I think when I moved from here to here, the interesting thing is that when I place here I don't notice there is gap between them, so now I become like aware of the gap, and I'm thinking about like what difference the gap will make. Now some are with no gap. Here, here there is gap, which is the thing I don't notice in this place, but now I'm thinking about whether I want a gap or there is not gap. But now I think

gap is good, so making more gap [ah its nice you can become aware of it and the maybe…] yeah it looks like when you look at the section and then you go to the plan, like when you change something in the model, but you won't notice there is some potential something…like a risk in the section, and basically if we have the model we seem to get everything, but perhaps we also need section or plan to understand the space in a more specific way, this feels the same [ahhh change the position and get some other information] yeah. Cos when you…I don't know, before those CAD software we seem to only have…[maybe just drawing or models from cardboard] yeah yeah, but I don't know [I think in the past people used to rely more on the drawings] yeah [today everybody looks at the model] we export from model. Some people have a good sense with a model, like when you look at the model you know something is wrong or not, but to be frank I'm not the kind of person who is comfortable with digital models. I really lose the sense of scale [I know what you mean, it's not so easy to feel the real situation from the model] yeah I get very, like I get trapped in detail when I'm making digital models. I think I should be aware of that and focus on the main point, but still I think when I'm using the digital model, it's more detail than making a physical models or simple drawings [ahhh true, you can always add more] yeah transfer from one direction to another its good. So I like the gap between cos it makes me feel more like the valley [ahhh ok that's nice] yeah cos you know sometimes you will have a valley in the really mountain and sometimes you do not, so I move this to here….hmmm, but sometimes I'm not going to move this from this cos it's too like, not natural [yeah] its going to collapse [*laugh* yeah it doesn't hold] but this is safe, so perhaps that's the change I will make. [This is nice. So you imagine this is something like in nature, some kind of scene from nature?] yeah. [ok. That's nice].

A.3 Instructions Given to subjects in Team Sessions

The observer opened each session by asking the subjects to take a seat in the two chairs next to the desk. The following instructions were then read from a tablet device, one by one, making sure that the subjects understand each item:

- In front of you there is a tray with sand and a box with rocks to be placed in the tray.
- Please work together and use the above to create a design for a miniature garden.
- Please refrain from placing one rock on top of another, or outside the sand tray.
- Other than that, the activity is generally free of constraints.
- Accordingly, the design may or may not have a theme or "concept".
- The total time available is one hour; this may be extended if you wish to continue.

- During the whole activity, we will use the "think-aloud" method.
- In order to become acquainted with this method, we will begin with a short practice session. Please find and pick up a rock which you like. While doing so, try to explain why you chose it, what is interesting about it etc., as you go.

Notice that the last instruction was given only for subjects who did not have previous experience with designing in a think-aloud style. Following these, the observer asked the subjects if they had any questions, and answered these questions. Typical questions were "are we expected to use all rocks?" and "do we need to make a traditional garden?". The observer clarified that, except the above, there are no additional demands or expectations from the design. When all questions were answered, the subjects were instructed to begin designing.

A.4 Transcripts from Team Sessions

We provide the full transcripts from the team design sessions below. Each sub-section corresponds with one full design session, conducted with a pair of subjects who worked as a team. When the subjects produced more than one design solution, we have separated the transcript into compositions, each introduced in curly brackets in the form {composition no., starting time}. For the first composition in each session, the starting time is omitted. Subjects' utterances are preceded by a single capital letter followed by a colon. These letters correspond with the fictional name assigned to each subject (after anonymization), which was used to refer to the subjects in the body of the work, when discussing and analyzing design sessions. Finally, the observer's comments are preceded with "OB-Y", followed by a colon.

A.4.1

{1st composition}

OB-Y: Ok, you can start.

T: do we need to use all the rocks?

OB-Y: ...these ones, and these ones, you can use all of them if you want.

K: I want to put a big one, and you?

T: I think a big one is better to decide the space.

K: yeah, to control the place...

T: make the boundary here... I think this one, they have similar colors.

K: yeah it looks like, the same.

OB-Y: like the one that is already there and then a new one.

T: yes. And...maybe I would choose all the rocks with a similar color first, what do you think?

K: oh yes, so I will...so...similar colors to...maybe have a different shape, but almost look similar.

OB-Y: ah, color is very close, but shape is kind of...

K: yeah shape is different.

T: I think maybe he is making all the rocks align, maybe I will just follow him to make mine like this

K: yeah, but the line should be...break (broken) *all laughing*

T: Ok. I think I'm gonna...the shape of the rock should be smaller and smaller in this direction, maybe like this, and...what...like this? Maybe like this?

K: it's like a dragon or fish...*laughing*. So I want to make it like a stone, of you know, a dinosaur.

OB-Y: can you show where is the head of the dragon?

K: yes this one.

T: it's more like a fish I think.

OB-Y: hmm, so either dragon or fish...

K: or fish. *K and Y laughing*. So I want to make it uh...the tail yeah

T: the tail...

K: the tail longer. But it should have some, you know, it have (has) some food.

OB-Y: ahhh something to eat *laughing*.

K: like this

T: here?

K: ohhh, maybe this one is bigger, this one is bigger....oh. Like dinosaur *all laughing*

T: think I'm gonna put it here...

K: maybe this one looks like (it does) not belong to this...It should be separate

OB-Y: hmmmm

K: maybe it is the food

OB-Y: ahhh, did you do that because of the color?

K: yes the color

T: I will put a big rock here, because I want to make it more...better balance in the picture. This is very heavy...volume.

OB-Y: ahhh.

T: so make another big rock here, they look similar

OB-Y: right...right.

T: so I put another one here to balance...

OB-Y: the whole

T: the whole picture

OB-Y: hmm that's nice

T: I think I should make some group, groups of rocks at one place, because this place is very heavy, this part....so what should I do...

K: oh...complete a fish.

OB-Y: ok I K thinks it's complete, then it only depends on you if you want to add or change something.

K: yes, for me it's OK.

T: *laughing* I think our topic is totally different, he is trying to make the fish, and I am just trying to make the picture beautiful *laughing*

OB-Y: which is good!

T: I think...

K: so we can make a beautiful fish...

T & OB-Y: yes yes.

OB-Y: yeah its completely fine. hmmm, you can work from different perspectives...

T: ok that's a fish, I think it should have a beautiful tail...like...but if the tail is too big, this won't look like a head

K: the head is very important

OB-Y: so what do think about it like in this situation? How do you think about the head and the tail?

T: maybe I will gather all the small rocks at the tail…place, to just show the boundary of the shape...and put all the big rocks at the head part

OB-Y: hmm...that's also ok to pick some rock from some location and change...if it's necessary

T: like this...I think that's enough...

OB-Y: so K, what do you think, is it a fish, or a dragon? How do you think about the final result?

K: the result...is close to a kind of dinosaur...*T laughing*

OB-Y: dinosaur? T?

T: I think it's more like a fish...

OB-Y: more like a fish...*laughing*. But anyways its quite nice

K: maybe a little like a bird...bird-dinosaur.

OB-Y: bird-dinosaur...*T laughing*. So it's flying...?

K: yeah can be flying. So for me, because for this kind of stones, I will remember dinosaurs first...

OB-Y: ahhh

K: and...the rocks in the sand.

OB-Y: so its two things that...like immediate association. Like you see the rocks and you think about the dinosaurs?

K: yes.

OB-Y: hmmm...that's interesting

K: maybe because I visited the dinosaur museum in Fukui

OB-Y: ohhh, did that happen recently?

K: no no, maybe...September

OB-Y: September...hmmm. So how was the museum visit? Did you enjoy it?

K: its designed by Kurokawa Kisho

OB-Y: ahhh famous architect

K: outside it's just a very simple wall...but inside have many exhibitions

OB-Y: that's interesting, I want to see. Maybe you can show me after the experiment.

K: yeah.

OB-Y: Why did you put that one?

T: I'm not sure...

OB-Y: that's Ok

T: I think this part each rock are separated to (from) each other.

OB-Y: Ok

T: Maybe some of them should be gathered together and the rhythm would be more...like...more like a rhythm. Some of the rocks get together and some are separated

OB-Y: Ok, that's nice. If you don't have a reason sometimes that also OK, you can say I don't know. But I can understand what you are saying...if you put them closer or farther they can be together or separate. I would create some pattern.

T: yeah. I think that's enough.

OB-Y: Very interesting.

{2nd composition, 9:34}

K: you do first...

T: Ok! I put the biggest at first...this way is better...

K: oh, in this way, this time I will use a different aspect...different color

T: so what's the topic? What the topic this time? *laughing*

K: diversity...different

OB-Y: diversity, hmmm...

T: OK. This...this...

K: yeah...make it more different, differences....and maybe a small one...and something...but still you know becomes smaller and smaller. It has the...you know...this big stone has a center

OB-Y: ah it's a center for the other ones?

K: yeah yeah yeah...it's a very strong influence, one we cannot neglect

T: oh

K: it's being controlled by this...many...this kind of uhh....you can see another center because of this color.

OB-Y: where is the second center?

K: this one

OB-Y: ah!

K: maybe we can make several centers

T: so there is no center at all right? *all laughing*

K: or...I think its weaker you know. We should put more stones here, here. And also this one is still the center. We make some changes...yeah

T: maybe I put all the small ones...because this part is a little crowded, so I wanted to make some little spot, at the other place

OB-Y: ahhh, right there are many rocks like, very very close to that one...

T: yes, so the smaller ones just separated this place. I'm always thinking about the balance of the picture! *all laughing* I just can't help doing that!

OB-Y: it's very important for you...I think when you make something minimalistic it's very important to keep a balance, there are not so many things here

T: it's too big...this one...this one...no...this one...I think it can be here...what should I do? I think it's enough.

OB-Y: it's enough? Hmm, so what do you think, can you say...uhh try to criticize this kind of design, or say, if you like it that's also good. What do you see in this one?

T: hmmm, I think we achieved the topic we decided at first

OB-Y: oh

T: the center, maybe this maybe this, the center, and it just fades out from the center of the groups

OB-Y: ah, I think so too. K what do you think?

K: hmmm, for now, I think still this one is still the center. I can feel small centers like this and this.

OB-Y: ash, there are different ones, but this one is still the main one...

K: the whole, whole yeah. It's like Japanese gardens....One center, one lake, and small lakes

OB-Y: ahhh, and they somehow...they relate to each other

K: yes yes

OB-Y: hmmm that's very interesting. For me what is interesting is that all of these are kind of flat, and then here there is vertical vertical vertical....I wondered if there was a reason to put these ones like this...the standing ones around the central one

T: because the shape of the...hmm...if you see not from the top, from this direction you can feel the rhythm, the changing of the height.

OB-Y: ahhh, changing height like from small to large and then small.

T: yes.

OB-Y: that's interesting. Very nice.

{3rd Composition, 16:18}

T: you go first

K: I think I will put this one in the center...because it looks very hard. He has very certain shape, this stone, this beautiful stone, can be the center.

T: ok...what should I do...I have a very similar one but...

K: *inaudible*

T: so this time what's the topic? Center, at the center?

OB-Y: By the way even if you don't have a topic, that's also ok. Just something aesthetic is also fine.

K: yeah I give you a chance to put...another center *T laughing*

OB-Y: ohhh *laughing* that's interesting

T: maybe put it here. (Tone of discovery) It will form another center

K: yes

T: maybe I should put it far away

K: I think this one is...

T: very similar? Oh oh.

K: yeah. This, this and this (adding), oh wait, this. Also I think these colors...

OB-Y: what do you think about the colors?

K: its changed.

OB-Y: ahhhh, from kind of black to gray, something like that?

K: yes. And then, maybe outside can be different...put all my stones here *all laughing*

T: OK. Because all the stones are gathering there, maybe I will make a line, a very long and thin line like this, or like this (pointing). Ok.

OB-Y: so...OK, first I want to see.

T: the shape like this...this (pointing and moving hand). (Long pause) Yes. Ok I'm done.

OB-Y: so the rest of the shape is based on what you saw before? How is it...?

T: because he made a shape like this (pointing)...

OB-Y: uh huh...

T: so I think maybe I can make a curve...connect this shape to the whole picture, so there will be a line like this...and then the whole picture would be finished by a round shape...and a line

OB-Y: ah, so somehow it's continuing the previous shape

T: yeah.

OB-Y: that's interesting. K what do you think?

K: umm...it's like a..flower.

OB-Y: hmm, which part? *laughing* which part is the head of the flower...

K: this one

OB-Y: ahhhh that one....so this is like the center of the head of the flower

T: yes

OB-Y: something like that. Did you plan this?

K: I didn't mean to plan this, just wanted to make a center, but she developed...she wanted to be (have) a line and center...become flower.

OB-Y: ahhhh, it's kind of combination...eventually ends in some kind of, whole structure of the flower.

T: I didn't mean to make the flower, I just think he did it already, and I want to make the rest part of the picture. Finish the rest part of the picture. But it looks like a flower, it's nice.

OB-Y: hmmm it does. It's quite surprising. So...you were thinking about one thing, you were thinking about something else, and combined, it's something different.

T: yes

OB-Y: *laughing*

K: this is...this is different

OB-Y: yeah yeah...the center flow of the curve, then we get this final shape, which is very nice.

K: ok

OB-Y: I think it's perfect.

A.4.2
{1st composition}

W: and we don't need to use all of it…just something we like (confirming)

OB-Y: yes, even one rock as a design is ok *all laughing*, if you want. Maybe difficult to make an interesting design like that, but that is also possible

W: so we start? OK

R: I want to see your stones…

W: it's the biggest one?

R: yeah, I think this…

W: and these are smaller ones

R: Yeah, maybe this one is the tallest one

W: oh, I like that…there's some special spots

R: yeah yeah yeah, me too!

W: so how about putting in first?

R: yeah yeah yeah, I think so. Because just like you said

W: usually when I put something, I don't want to put on the center

R: yeah, me too! *W laughing*

R: I just want to see this line or this line (lines of thirds)

W: ok here.

R: ok. And…because it's very sharp, yeah so I just want to categorize the stones, yeah yeah this one, we can see clearly, this one this one is not so sharp…and…looks more cute

W: *laughing* yeah

R: yeah

W: this…

R: yeah maybe….can we just put the stones by group or this group…some part is sharp one and…change the style

W: ah ok. I think these two are similar

R: yeah looks similar. So actually, I don't want the same stone appearing at the same time

W: ok

R: maybe we just try the other one, if it's needed we can put this one

W: yeah.

R: ok bye little guy….

R: I think maybe next one… how about change to a lighter color…?

W: ohh

R: I mean this this one are also the dark color, so I just want to put something…

W: different

R: yeah different. I think by this center…

W: these are lighter

R: yeah lighter. And this one (is) lighter…

W: I think like….this color is a little similar, close to the sand

R: ahhh yeah….yeah yeah yeah a little bit, maybe next… I thought that it has the same elements, maybe this one is more suitable….

W: comparable…

R: yeah maybe they are the good…we just put there…it better?

W: this makes me think about Oreo

R: yeah yeah yeah…it looks like, I don't know if you see clearly, I think the shape might…a little bit match together

W: oh, oh I can see. yeah yeah I can see

R: so put here, OK?

W: anyway you like (is) ok

R: just put here for now, maybe we can change

R: another….

R: and these two are a little bit heavy, looks like heavy, and tall…maybe try something like not so thick.

W: like….hmmmm…I think this looks like a staircase

R: staircase...(wondering) ahhh right! a little. Actually I don't have any topic for this one

W: me too

R: so just put it freely?

W: maybe…

R: maybe…

W: I don't know

R: not sure…

W: I think, ummm, I don't know I think if these two appear here, I think, nothing can go into them, or around them.

R: maybe they are already settled down

W: but I would like some small decoration

R: OK! we can put…

W: like this…

R: ahhh, also good!

W: this is sh-…do you think we should have some rounded one, or the whole topic…the whole things are sharp?

R: hmm, we can try…

W: then see, uhhh

R: yep

W: maybe a little front…

R: yeah

W: I'm not sure, please adjust

R: uh…

W: but I think that doesn't work better than this one

R: yeah I think so, because it's like, standing in the same distance and….

W: father, mother and child

R: *laughing*, yeah a little bit.

W: hmmm…

R: how about the other place, just put it here, maybe we can find some clues

W: ok

R: yeah

W: so would you like to try something not very thick

R: yeah, I always want to try this one *laughing* I don't know… I just think if its tall enough maybe we can put into a large area, not only this…

W: uh huh

R: can I just put here?

W: ok

R: cause I like to put things maybe yeah, these two lines, third-third-third

W: ok (smiling)

R: hmmm, and….

W: should we see from an angle like god or just small visitors?

OB-Y: so there are two options - one option is that we just looks from this eye-level like we are looking at it now, and design it like that, another option is to imagine a different scale. If you imagine a different scale you can use something to illustrate.

W: ohhh

OB-Y: to show what is the size of a person or something, if you want to use a different scale

R & W: ok

OB-Y: But it basically depends on your decision.

W: Ok, thank you.

R: yeah, seems stuck.

W: (smiling) it seems these two are totally different.

R: yeah

W: maybe it doesn't fit

R: yeah

W: maybe…it looks a little strange. and if I put here I think, this looks like something delicious

R: something delicious (wondering)?

W: I think like a basket, and this like nuts.

R: ahhh maybe

W: but I think it doesn't fit

R: yeah, for the fit I think also it doesn't fit.

W: this one?

R: uh hmmm, ok you can try.

W: but, hmmmm

R: how about we put…I think it's almost the same line

W: ok

R: maybe we can change to this one…or yeah…I think it's not beautiful enough…hmmm…you can change the angle no problem.

W: ok

R: or put…no I think…about this side

W: or maybe this side is better

R: yeah I think so

W: and…maybe…hmmm…hmmm…because I think, I think (shows a gesture of cutting with hand)

R: ah yeah, shape like a knife, cut it

W: yeah yeah

R: hmmm, maybe we need more stones to put here

W: let's try.

R: yeah I think…

W: I don't know I just want to use this one

R: yeah, oh yeah because its special. hmm, ah (discovery) it reminds like, it looks like "nu-jah" (historical character from Chinese legends with a tattoo on his forehead). Do you think…?

W: like…what…

R: with the tattoo on the….

W: his…head

R: head, yeah the center of the head. And it's a little bit looks like…

W: I think it also looks like the lotus

R: ahhh, yeah yeah yeah, yeah! it's true. cos' you said lotus, it mean you look at this one like the flower, the other…(signifies leaves by cupping hands)

W: ah like the…big leaves

R: yeah, I thought I treat this one as eyes, yeah. Eyes and the center…

W: *laughing* oh ok

R: I also like lotus, yeah. Yeah I think we can treat this like a pool, or it's the…it's the mother king of the lotus…

W: mother king?

R: the king of the lotus

W: oh…

R: yeah

W: do you think these two have a connection?

R: No!

W: me too, I mean, me neither.

R: ahhh, yeah. Yeah. We also…if we shape like a lotus…how…I think it's not enough to look like, for….maybe for this one, because lotus is the whole, maybe the around will be all…

W: no like small petal…

R: yeah

W: but…

R: choose…choose…we can try to put something, if it didn't look so well, we can…

W: ok

R: how about put, put down…? look more like…

W: like it already bloomed

R: yeah, yeah. Can you imagine that flower in your mind?

R&W: yeah!

R: yeah me too, I have the same, I think we have the same…yeah. How about we…I think this shape is good. But the color is so, looks like the center one, because the other one is almost light, and I have a little bit yellow.

W: yeah, but other stone…I think might be too high

R: yeah, yeah yeah. It's a little bit....hmmm? this one? how about this one?

W: hmmm (a bit surprised). But if you put it here it suddenly changed. I think it looks like these three, four things are surrounding this special person or something. Like…

R: yeah

W: what did you put?

R: here (hands rock)

W: when you put here it makes me feel like this one has no help and lonely

R: yeah. Oh what I think is…it's a whole flower, and this is the center of the…

W: oh, that also makes sense to me (confirming positively)

R: yeah, what you thought is that this is a leaf…circle one…

W: no no…if you…in this way I don't think…if you put it here, I don't think it's still leaves and flower. I think the surrounding one are all petals…of flower

R: so we remove this one?

W: but I think it's also ok…it's also *inaudible*

R: which one is good?

W: I think maybe put…(points right)

R: put here?

W: yeah. And I think that this is bigger, and these two are bigger and these two are smaller…and the color is also like this is lighter these two are darker

R: yeah

W: this like, this is…these two are fresh…fresh petals

R: um um I know

W: and these are already…already go out for a little while and already grow

R: yeahhhh. Okkkk. Yeah, we can explain this way

W: and it makes me feel dynamic

R: ah right right!

W: something is moving this…something smoothly changes shape, color

R: yeah, like the real flower

W: yeah yeah yeah

R: hmmm, nice!

W: I think this…finished

R: yeah, but this part seems strange.

W: a little. Is that because this is too close?

R: yeah maybe but…I tried to find a connection between this one, maybe we put some…we form some small flower, it's the biggest one here and the center, and maybe the other place need, needs…needs some small size one?

W: to make some other flower?

R: yeah, maybe the small one… can I just put it freely?

W: yeah of course

R: um hmmm… actually it's not the same…same feeling stones. So this one…is also the, maybe (show similarity in sharpness to another rock by hand gesture)

W: ohhh

R: yeah.

W: but other stones…ah no. How about changing idea, like this time use a rounded one?

R: ok…hmmm

W: but rounded stone only has two (stone collection available is limited)

R: yeah…yeah there's no…hmmmm

W: I think…I think I can tell a story based on these two

R: yeah

W: you can see that the center one is black or dark…

R: uh huh

W: dark one…and imagine that the surrounding one is his friend…and ohhh…at first he and his friend are both very sharp and…ummm…uhhh I mean I use sharp to mean that the person is not

R: to characterize

W: oh yeah yeah

R: is not friendly or something…?

W: like special…stubborn. And after suffering many things, some of the friends (are) gone

R: I know…I know how to say in Chinese "zhu zhie yuan ren"

W: (speaks Mandarin) dui (translation: correct). Some of them gone

R: ahhh yeah

W: leave, leave this one…

R: ok

W: and remains one, and the center person, are both being shaped by the tough life

R: yeah! we can…

W: like a rounded shape…

R: we can translate into the…

OB-Y: ahhhh

W: like somebody leaves, and somebody turns to another shape, and also yourself

R: yeah, because this color looks like it, and this color look like it. Yeah! I totally agree

W: and they lose many things

R: yeah yeah

W: not only the sharp angle, the sharp things

R: yeah…

W: (speaks mandarin) ci (translation: thorn)

R: I don't know…literal

W: something like needle

OB-Y: ahhh yeah

W: like the…sharp

OB-Y: sharp angles…

R: yeah yeah yeah

W: and if we hmm…imagine that this is the most important thing of your life, and you lose other unimportant thing, and you can only hold and keep the things you really really stick to, and you lose other things

R: nice, nice explanation…and…I also look at some part of their partners, there are three stones…

W: yeah

R: how about…how about…ah sorry, how about this part?

W: hmm, hmm, black and white?

R: because for now the meaning is good, but I think it doesn't looks good

W: you mean this single one, or…connected?

R: I mean, as a design of this one (signifies the whole tray with a hand gesture) as a whole design. hmmm. Maybe for my view…

W: point

R: yeah view point, and for this angle it's not so bad

OB-Y: you can also change places if you want, or stand up…anything is ok. Like this seat is only to make you comfortable, but….

R: yeah yeah yeah

W: I agree with what you said. This angle looks not bad.

R: yeah because they are almost at the same line (pointing to the two back compositions) and this one from this way to see is…is disappear.

W: yeah but from other angle you can see it

R: I think it depends on which angle we choose

W: yeah

R: but not bad!

W: um (agrees)

R: actually I don't know how to explain this, this part…because this part this part we already built a connection…hmmmm

W: well…let's take out first…(both remove the back left composition together)

R: yeah

W: and then...

R: I think now it's much better! *both laughing* yeah

W: yeah

R: yeah yeah…maybe we just freely put some small stones, and for the decoration, maybe no meaning.

W: like to show the difficulty in life, to like the outside things that make him become him

R: also ok. Maybe, yeah nice

W: I don't want too big things

R: yeah I also choose the small ones…so so sharp

W: ummm….looks

R: maybe far, need (to be) far away from

W: ahhh, I think…

R: not the one you like…

W: yeah. I think doesn't have any connection, but if we put it close it will destroy the story of these two

R: yeah. But I still think only these two (compositions) is not enough

W: hmmm

R: hmmm, because if you draw a line here (divides the tray diagonally with a hand gesture) we can see we almost put everything at this side, and…its empty here

W: how about…maybe we put something more at the corner

R: yeah, maybe we can try, and if it don't looks nice we can remove, we can put…

W: I think this is very sharp

R: sharp yeah

W: I want to use this

R: yeah, um hmm

W: and maybe smaller one…and maybe another color….

R: yeah…it also forms an…

W: I see it turns to something like…

R: yeah…how about removing this one, because it's so dark like the center color, so maybe it will…will let somebody notice this corner as an important part of the whole design

W: ok. How about this color?

R: ok. Try

W: looks like a face (smiles)

R: yeah, I also think, joker or doggie. Maybe how about putting here, far away from the…hmmm, maybe another partner for this stone…hmmm it's so dark. Yeah, there is no little stone.

W: yeah

R: but I think little one…hmmm, I just changed the position freely to see which looks more pretty (seeks confirmation). Or remove?

W: but I think this stone is…hmmm…something special

R: yeah, I think so…

W: with many…

R: yeah yeah…its roughly…

W: yeah and not like other stones (where) the color looks as a whole, it has many different colors and very rough

R: um hmm. I changed this angle because I see from this view if we put it like this it becomes too big. From this angle it will looks small-ler, yeah smaller. I don't know…it also looks strange

W: yeah I think so.

R: yeah…maybe remove this one?

W: hmmm…

R: (sighs) what do you think?

W: oh (discovery) I think maybe we can take, take out, pick out some special stone, and just arrange them to show different kinds of people

R: ahhh ok

W: like the stone…let's pick it first

R: ah right. Maybe this one is also sharp but they don't need to stand, they put and lay down.

W: ohhh. But, can I just (explores possibility of adjustment by making the same rock stand)…I want to see how it works…if it stands up

R: *laughing* no….I think from my angle, you can come here and see, it's like a rabbit ears

W: *laughing* ok

R: but also I think it's quite good. Much better than just *inaudible*

W: how about this? maybe this is sharper

R: yeah

W: and stand, oh stand

R: but I think this one is better because…I think its…hmmm, how do you say (speaks mandarin) zhong dian

W: oh, stress point?

R: yeah, stress point. Maybe if we put it

W: this one?

R: which stone did you pick? maybe we put it here

W: oh, like they don't have

R: yeah, maybe it's so balanced. Maybe we want to let somebody focus on this process, there from the sharp, to the…

W: round

R: to round. But this one is to show the other sides of people in the world

W: yeah

R: maybe they are not the biggest part, so maybe the small part is ok?

W: yeah

R: yeah it's also…

W: small

R: yeah small. cute. Yeah, maybe, yeah I also want to say put some some…

W: eh? but…eh? (surprised and wondering) Do you think it turns to something that is opposite from this, surrounding one is taller, the center is smaller (seems rhetorical)

R: oh yeah…yeah. We did not on purpose form that

W: yeah…but I don't have…we don't have…just strange

R: yeah

W: (sighs) oh, ohhhhh I know, I know (discovery, expressing confidence). This is the childhood. The girl (pointing to tallest rock in right composition), these are some of her parents or relatives, just protect him, and they (are) all gone, he has some other company, some other friends

R: um hmm (agreeing)

W: and this which is her…his parents already dies, and he (has) grown up. This is this (points to the back-left composition). And has some other friends…

R: um hm.

W: and then this (gestures with hand to show that the front composition is the next and last in the sequence)

R: hmmm. Ok

W: how about changing the position? this this…

R: yeah, I was just thinking about the position. Not good…Maybe put this one (gestures to right composition) a little center and far…a little far away

W: oh I think so

R: yeah, just together to move this one…it cannot stand stable. Nice.

W: so how about this, should we move it? (points to right composition as one unit)

R: put here maybe?

W: you mean this one or this one?

R: this one

W: here, it turns out like this (shows a curved line of flow with hand gesture). How about move it more…center, and this… (points to front-middle composition)

R: I think more to the center is already…so center…

W: maybe…

R: yeah ok.

W: hmm…

R: let me check…do you think it's enough?

W: I think so.

R: me too. Even though I think maybe, (if) there will be one stone maybe here or there, will be more complete…

W: maybe…maybe these *inaudible* are too big

R: yeah, yeah. For the aesthetic I think it needs something else. But for the meaning, for the story, I don't need anymore, how do we balance it….

W: I think it's enough

R: yeah because the story is more important than…

W: yeah

R: yeah, Ok

W: Ok finished

R: yeah, we changed a lot!

A.4.3
{1st composition}

H: Ok N, I think let's start. I would say, the younger...younger person first.

N: I am younger than you?

H: huh?

N: I am younger than you?

H: I think you're younger…maybe. *N laughing* How old are you?

N: 26

H: I'm almost 30…

N: ah…younger

H: So…you have more spirit.

N: Ok. I want to just focus on the color as well, not only the shape. Uhhhh….

H: What are you aiming for?

N: That's a good question. *Both laughing* I want something, how can I say…the…uhh….you know the Ryoanji in Kyoto, only the rock and sand one?

H: Yes

N: Uhh…I like, I prefer the opposite one, with the green and rock as well, like the natural garden. So maybe I will need to like express the green stuff with doing something…*laughing*

H: um hm (understands). So the green garden with the stones?

N: Yes.

H: Ok

N: That's my aim.

H: That's you aim, ok I see *N laughing*. Do we have to use all the stones?

OB-Y: No. Even like two rocks is fine or something

H: Ok. But at least one…

OB-Y: At least one, yeah that's the limitation *smiling, N laughing*

N: So, then I will choose something which reminds me the green thing from, from among those stones…this stone looks like…a tree top…but it's so detailed…so, maybe I want, I will place this like the closer to the front…in that sense…this really looks (like) a rock itself

H: maybe if (hold rock vertically)

N: Oh what about like facing in the vertical way

H: Yes

N: Ah yes yes, that looks like the column

H: And then…

OB-Y: Sorry to interrupt, if you have one that you are thinking about, you can show it to the camera too

H & N: ahh ok

H: I was wondering if we, when we put this one vertically, I might come close to a tree.

N: That's true.

H: Ok.

N: Yeah this too

H: Ok so let's place them, randomly. Somehow randomly.

N: Ah hat's nice, yes

H: yes

N: But somehow…ahhh (discovery) now that area looks like a forest.

H: Start to…create a forest. So you think we should go in….(looks like change of mind) oh this looks like a pine tree

N: ah right

H: so if we place it like this it comes more closer and closer to a forest.

N: Um hm (agrees).

H: But maybe we should not like…now I feel they are all in the, in the direction, like even if we place like this, to become more like a forest (slightly turns the last placed rock)

N: right, like…random

H: Yes

N: varieties…

N: those…

H: I think it's very interesting to put them vertically

N: um hm, right – that's true.

H: so maybe we should change this, the position of this one, to more in a vertical direction (flips existing rock) oh (discovery)

N: oh that looks…that's interesting too

H: and this looks more like a…not like a pine tree. Like another tree. Ok this is a small tree. Hmmm….maybe it's close to a bigger one, so the seeds from the bigger one fell down, and then the smaller tree grow close to the bigger one

N: like this?

H: That's very nice. I was just wondering, that this looks more like a…a…like these are pine, and this looks more like a…oh what is the opposite of pine?

N: ahhh I don't know

H: like this (points to tree outside window) kind of tree

N: ahh, yeah I know that. Like…

H: with a lot of leaves yes…but its…

N: ah so in that sense, this looks, but this is…

H: But, but I have an idea, like a bird flew…shit here…and then from this shit, like the tree..

N: ohh ok, that's possible

H: so this is natural…

N: like the time line

H: yes. And then the forest starts to grow. But I was wondering, like when I look here (directional gesture with hand)…if there might be a…a path

N: path (confirming)

H: through the forest. Like, a path where people walk, like small cars…maybe car, not cars, but are going, so not to cover all the space, but

N: ah so you are imagining like this garden will be on…like the mid…ahhh…like in the city…or in the…like in the villa

H: now my imagination is not a garden but like a forest. Like we build a forest.

N: yes

H: and this forest…just I am sitting here (showing the direction of his point of view using a hand gesture) so I am imagining myself like standing here, looking in this direction, because

in this position from my…I look here in this direction, so for some reason right now, I see like path here, or a street. And I have this idea of "OK, let's keep this path".

N: Ah ok

H: from your perspective there might be a path

N: yeah that's true, it's a path here also

H: but how about imagining, you are standing in the forest, and I am standing on the path

N: ah, like here, you mean…like collaborating the forest and path

H: yes, yes. So we just have one direction of path, and you look out of the forest.

N: Ok

H: and I basically looking from the path into the forest. And start to compose the stones like this. I don't know.

N: yeah that's a nice idea *both laughing*

H: ok so, I think we should mix the tree, and another, so maybe we...yeah, I feel like placing it here.

N: um hm. This is (an) interesting shape…for the forest. Ah (discovery) there should also be probably like the old tree which already tore down

H: ahhh yes!

N: so at some point…hmmm…but I don't want it blocking the path, also.

H: but how about like having the path like here, and then one tree is like, not covering the whole path, but just a part.

N: uh huh.

H: so like this…

N: yeah, um hm.

H: yeah. and then I just let another tree grown here. Just…ummm, yeah. So now here…

N: um hm

H: is kind of the path…maybe we have to place this a bit more here

N: um hm, yeah

H: yeah, still the path

N: um hm. Hmmm….

OB-Y: H can you show with the finger where is the path?

H: um hm. I imagine just looking from here, and this direction (pointing with finger and moving hand).

OB-Y: ok

H: I am not sure if the path is going straight or a bit curved

OB-Y: um hm

H: but like this direction

OB-Y: ok

N: hmmm, I prefer the path would be, like a bit curved as well

H: um hm

N: so maybe this kind of small…

H: tree

N: trees yes

H: oh that's very nice, now it make like a curve like this

N: yes

H: and maybe it goes here

N: um hm

H: so we can place one more here…maybe a big tree

N: um hm

H: like this…oh it is difficult (rock would not stand easily)

N: oh, that's quite nice

H: and now the path goes like here (show that the path is curved with a hands gesture)

N: that's quite nice, yes. Hmm…probably one or two more stones

H: yeah

N: at some point…

H: or maybe we can use the whole stones (all of the stones) for a very dense forest

N: ahhh, but…right now the density of this garden or this area is quite same…I want some point like the density…more dense…probably here.

H: um hm. How about filling this area?

N: hmmm…yeah that's what I thought…*laughing* I'm thinking, this…this is…for me it feels like this here in this side will be like less density

H: um hm

N: because some trees are already…collapsed

H: ah fallen, that's good

N: then, the left area would be like more density…

H: hmmm…

N: to me…so…hmmm…maybe this stone…would be here

H: yeah *N laughing*. Somehow this composition here is very, 90 degree angle.

N: right! *laughing*

H: and it looks very…and…the distance from the

N: ah that's true

H: it looks very artificial.

N: uh huh.

H: so…I think we should place a stone, either we have to rearrange them later, but lets start to place a stone very very like…on the corner.

N: um hm

H: like this

N: ah that's true

H: to break the…now it feels…yeah

N: then…I will put, a round shape….

OB-Y: N, why did you pick that one? was there a reason? if there isn't a reason that's also fine

N: hmmm, I would say there is…yeah basically I didn't think…just from my feeling, but probably I will, one reason for choosing it was like the size. I don't want like this big stone on that place (holds a bigger stone for explanation purposes).

H: I feel like grouping. I like this composition of a group, so I think I want to group and to put a smaller one.

N: um hm.

H: or maybe its fine like this, like this like…group of two trees

N: oh right…

H: but I don't know if this one is suitable. Maybe this one…yes, like this, very close together.

N: um hm. Ahhhh…

H: because the distances here they…

N: they almost seem

H: very similar

N: yeah right. What happened if I make it closer to here…

H: yes. Yes, much better.

N: ahhh, um hm.

H: and somehow this, from my point of view this one looks also a bit strange. I don't know…just a little bit here

N: um hm

H: and then…

N: ahhh the 90 degrees

H: yeah we kind of break this 90 degrees, I feel

N: now I see the…another path, like here….(showing with finger)

H: going through?

N: yes.

H: do you think we should break it?

N: the path?

H: yes

N: hmmm….no I think its fine to keep it. Like to keep the two paths.

H: um hm

N: like relatively…the wider path and like the smaller path like…for example animal

H: yes, yes! I like the idea, I actually had the same thought. Like the smaller path is more for animals

N: um hm

H: and the bigger part is for humans

N: yes

H: the humans they are not able to go to the small path, they don't really see it

N: yeah

H: but the animals they see it. I like this idea

N: um hm

H: I'm just thinking if we need all the stones…

N: hmmm….

long pause, examining the rocks that are left

OB-Y: N what are you thinking about?

N: I'm thinking about…uhhh…if…uhhh…how can I say…hmmm, I don't' want the garden to be too dense, but on the other hand, I also thinking this is….ummm this garden doesn't have enough stones…enough number of stones already, but…yeah.

OB-Y: ahhh

H: just wondering if we…just take those two very small ones (out of the rocks left), like maybe not using the big ones…

N: um hm

H: 'cause I really like this composition (points to composition in the front right corner)

N: yes, that so true

OB-Y: so you're considering to add more stones? (confirming understanding)

H: but only exactly two more stones…but only the two smallest are left.

OB-Y: ahhh

H: Because they are significantly smaller in size

OB-Y: yeah

N: um hm

H: (out of) all of the left over five, those two are very small, and uh…I was just wondering, I agree, like I have the feeling it doesn't need so much change anymore

N: um hm

H: but I feel, I don't want to make it too dense, as you say, but on the other hand I feel like…maybe these two stones, one or two of the smaller ones…wont', will change of course of the whole image but not that much anymore. And I feel already actually, the whole image feels…feels somehow… comfortable already.

N: um hm

OB-Y: that's nice

H: let's try one more small stone

N: yes

H: to place it. I, I think that this side is almost, almost fine

N: um hm

H: so I want to place this one…but I don't where, maybe we have to try out

N: um hm. Ummm…what I just eh, started to think is, like we have the two paths, for the humans the wide…wide path and like small path for the small animals, and…to me uh, by the humans' road has, like relatively bigger stones like this and this…

H: yes

N: and for the animal paths, there's some smaller ones like this and…

H: yes

N: for me, to me this stone (point to a short stone in the middle) belongs to the animals' path

H: um hm.

N: somehow, I don't know. This is also looks small, so…why don't we just put like this area (refers to area on the left of the tray with circular motion of finger) around this stone….

H: like here maybe…?

N: yes, based on the…like…

H: maybe like this?

N: I don't know…it's gonna be the principle, but…yeah

H: yeah

N: yeah looks nice

H: this feels good

N: yes, right now I'm…

H: yeah

N: comfortable with it

H: I was just, I hesitate to place the small one here

N: um hm

H: first I was thinking this this is still very empty, but ummm….I have to say, like I…yeah, I didn't want to place it here because then this gets too dense

N: um hm

H: and maybe like we feel the corner and then it's…it's out of the, I like the balance right now

N: um hm

H: so…

N: yeah me too

H: I agree to you…I'm quite comfortable with this, setting of stones

N: yes, I can say it's done

H: um, yeah

N: arrange…

H: yeah

OB-Y: very nice

{post-activity interview, 23:21}

OB-Y: so I have a few questions

H & N: Ok

OB-Y: First of all, just a small thing…I don't know if you remember, but I was wondering why did you decide to put a big tree here (pointing to rock in back right corner)?

H: umm, because my like umm, first my imagination was – I am standing on the street

OB-Y: uh huh

H: and looking straight

OB-Y: yeah

H: and through the straight view, I see the path. And then, N is saying like - 'but how about making the path curved?'

OB-Y: uh huh

H: and from my point of view, like I position this stone at the end of this imaginary path

OB-Y: yeah

H: and through that, the path is making it curve (the path curves) in this direction, and this stone is leading the path a bit left, and I can't see the end of the path anymore, it's not a straight path anymore but it becomes from this perspective curved.

OB-Y: yeah, very interesting

N: that's true (agreeing positively)

OB-Y: Ok, and…in the end I…a bit lost the…like track of the symbolism, so some of the things are trees? some of them are also people?

N: no, no people

OB-Y: there are no people in this…(confirming)

H: no people

OB-Y: they are just imagined…

N: yes

OB-Y: to inhibit…like…this place. They walk around maybe…

H: yes

N: yes

H: the idea I think the idea is that…this path here, is frequently…not frequently but people will go on this path. But only on this. And then we…we mentioned the animals (N agreeing), so I think from N's perspective here is another path

OB-Y: uh huh

H: but this path, like only animals use like

OB-Y: ahhh, ok

H: like fox or…

OB-Y: they are not represented here right?

H: no (confidently)

OB-Y: it's just, their forest or something and…

H: yes

OB-Y: really nice. The last thing, which is uhhh…kind of, it was a bit surprising for me…I want to ask H – how did you come up with the story of the bird?

H: the bird?

OB-Y: yeah, there was a bird that…uhh

N: you mentioned at some point

OB-Y: right in the beginning

H: yes (recalls confidently). So I was imagine(ing), maybe that my thinking was - 'ok this is a forest', and…I went very very back at the beginning of the forest, and then there was one tree. But the tree, so usually the tree, the seeds of the tree fell next to this tree, and they won't reach this point. Besides (the case in which) a bird eats the seed and goes somewhere else, and yeah shit there and through that the seed is going there, and then suddenly there, the forest starts to grow, this is the…

OB-Y: nice *all laughing*. Yeah…what…

H: I don't know how you call this but…yeah the…

OB-Y: some kind of analogy or…

H: yes yes yes.

OB-Y: from the real process of growth

H: I don't know where this with…the seeds and shit, I don't know I have, but I had the very strong image, true, in the beginning of…ummm, yeah, because of the mixture of…because the (imaginary) forest is out of pine tree and other trees

N: yes

H: and…in…for example if I imagine a pine…pine forest, why is at some point there are…ummm, other trees, like Gingko or…and this can only happen if someone is carrying seeds from one place to the other

OB-Y: hm

H: and ummm…the most natural way I came up with is, like the bird, eating the seeds and then…shitting the seeds

OB-Y: so eventually like uh, when you just looked at it…there was some difference

H: yes

OB-Y: between the two things right?

H: yes - so this one (points to black rock on front left corner) was for…in my imagination not a pine tree. And we placed a small pine tree here (points to the small rock next to it).

OB-Y: uh huh

H: and I was wondering, if through wind the seeds could not come here. So some other actor has to be there. To…that the pine tree is from this, comes from here, to the back side of the…what is opposite of pine tree?

OB-Y: there is a lot of…like coniferous, I don't know, tons of different…but I know what you mean, the leaves are more spread

H: exactly

OB-Y: Ok, let's say concentrated and spread

H: Yes

OB-Y: or something like that,

H: yes, yes

OB-Y: yeah the pine tree has a kind of very defined shape right?

H: yes, exactly. And has not leaves, basically, ne…(Japanese utterance similar to 'right?'). So, this was the imagination.

OB-Y: it was really interesting for me to see how your different choices, or you know integrated into one big story. Actually, you selected the first one, right? (referring to N). The…I mean for… (pointing at the first placed rock).

N: ah yes yes

OB-Y: for the different tree…

N: um hm

OB-Y: and then…you set up the beginning of that forest

N & H: yes

OB-Y: and then there was a need for some unifying story

H: yes

N: um hm

OB-Y: that was extremely interesting

H: but in the beginning like when N was saying he doesn't like stone…gardens so much, I immediately jumped on this thought,

OB-Y: hm

H: and su-…immediately my imagination 'ok let's make a green…', and for me a green was the forest

N: um hm

OB-Y: ahhh, hm, wow.

N: yeah, but I didn't…I didn't yeah think anything, until H asked me like 'what is your aim?' and…

OB-Y: ah, there was no…

N: yeah I was just…

OB-Y: like idea, until he asked you, and then somehow this thing came out

N: right right. I just took a random stone then put…at…yeah, nowhere

OB-Y: that's so interesting

A.4.4
{1st composition}

OB-Y: can you see if it's recording...Ok we can start

L& R: yes

L: choose the beautiful stone...

R: I want to have like a...like a corner garden

L: um hm

R: how about you?

L: yeah

R: like two corner...like different shapes

L: um hm...

R: in two corners and maybe...aa...I don't know like maybe one big in the middle, or we can like do and then decide the...like...put it first…

L: flat…it's beautiful *laughing*

R: ok

L: yeah

R: continue continue

L: want..have some...waves

R: like yeah yeah waves like...this...

L: to have this...or we put stone first

R: no no no, stone first? we don't have to draw the draft first…

L: *laughing*

R: finally we are free now ah? After the long long annoying course…aa...now I want to do is to design without reason...*laughs *

L: *laughing*, I see.

L: like…

R: let's be child again

L: yeah...I like this kind of zone

R: ohhhhh...then it looks like a sculpture, sculpture.

L: sculpture

R: ahhh I see...

OB-Y: don't be afraid to speak louder…

R: ahhhhh...ok

L: ahhh...I see...

OB-Y: because I'm recording, I will later transcribe, like write everything you say, so if you speak very low it's kind of hard to get the sound

L & R: ahhhhh ok

R: oiiiii...

R: then I will make some change to cooperate with you...

L: um hm...mm

R: yeah...this is a nice

L: yeah

R: sculpture, like...ohh I remember a science...s...ss...sci-fi…

L: um hm

R: ahhh...humm...science fiction, I told you before American series that expands the the the series about the the out space

L: ohh

R: there is a planet and they have a lot of big, huge structures that look like this and these, there was built, planted by some alien before and there was a nuclear...like ahh, how to say? Mmm how to say...factory, like mm how to say? *Speaks Chinese*

L & R: *laughing*

R: so to create electric electric power

L: I think it's common in Japanese culture...maybe…it can *inaudible* (hold a rock)

R: this one? It's not common, it's not common…

L: I think, I kind of seen, seen it in Kyoudou (place in Japan)

R: ahhhh...from...from my angle…you see...from my angle it look like the the the shark…

L: mmm

R: on the shark's body, like…

OB-Y: ah, shark's fin

R: yeahh...shark's fin...hai

L: *laughing* yes

R: looks not very calm

L: I see

R: eeee…

R: so we should...ahhh this like... look like a candy…

L: yeah, chocolate *laughs*

R: it's…it's ugly...huh...

L: stone from the…

R: but the colour is too similar

L: yeah, the brown things...

R: maybe this one

L: it's very…

R: mmmm...not bad…

L: yes, yeah

R: it's like a…when you do calligraphy…

L: um hm

R: it's like the the stone to to...how do you say? *Speaks Chinese*, to...

L: to...uh…*laughing*

R: put on the papers…

L: to fold

R: yeah...on the papers corner to make the paper flat…

L: maybe we can have some…

R: ahhh round...

L: right here...let's see how it looks…*laughing*, very circle...

R: ohhh you mean the Japanese garden

L: yeah

R: but our fingers is too thick

L: yeah

R: it needs...needs...it's like an island now…ahhhhh

L: oh it's cute

R: ooohhh...awwww...

OB-Y: you can use them (hands over miniature rake)

R: ohhh...so cute…ohhhh, oh it's like a mini Japanese garden tool right?

L: hmm, like something you can buy on Tokyu hands

R: yes the the monk...do it every day...like to clean the sand, right? So so so we should maybe use the back side

L: yeah

R: to draw the circle

L: yes...and this looks like…

R: every stone should have its own territory…

L: *laughing*, sometimes it's like...

R: ohhh it looks like a mickey mouse nose…*laughs* it's too even maybe...maybe some some someone should have a bigger…

L: other...some another stone here…

R: yess...put this one?...

L: eehh...it's too

R: it's a little ridiculous…

OB-Y: if you want to erase or flatten you can use that ruler, the black one, it's quite convenient

R: ahhhh…this? Use this?

OB-Y: yeah, yeah

R: ohhhh hoooo, ooohh like a *whisper*…ok…feel it

L: amazing…

R:...too...too lonely...

L: yeah too lonely, make some friend here *laughing*

R: I don't know…

L & R: hhhh...mmm

R: too small…

L: we can...like

R: ohhh this one…

OB-Y: when you say too lonely, which rock are you talking about?

R: they are all too lonely

L: all too lonely, and also we have the circle too

R: yeah separate them

OB-Y: hmmm

R: like like three islands…

OB-Y: ahhh

R: they don't talk to each other so maybe we need something to...like break this...thing...hhh...yeahhh...maybe they can be a group?

L: hm, yeah...and also, we can have...

R: do you think he is too small or is like a family? *laughs*

L: yeah looks like family *laughing*

R: but I like this one-

L: this one-

R: to be alone, to...because it's very unique, this…

L: very…

R: and…

OB-Y: can you try to explain in what sense it is unique?

R: hmmm, it's very tall...yeah

L: actually very beautiful *laughing*

R: the colour is...very...different from all the black brownish, uhh black or gray

OB-Y: hmm

R: the colour is yellowish

OB-Y: hmm

L: and you can feel the language...or something that that

R: yeah

L: it just stand here and you can feel it

R: yeah...it's, it's very thin but very tall…soo...has some spiritually in it

OB-Y: ohhh, it's nice

R: yeah but like they are more or less...common...sorry for the...for the...but this stone *laughs* so but one is very...different

OB-Y: *laughing*

L: it looks like...ehhh...how to say, it's kind of...mr...arra...arro

OB-Y: arrow?

L: arrow-

R: ohhhhh yess...it's it's it's a kind of aggressive...then maybe they should be in the corner… psss...to be the guard

L: yeah to be the-

L & R: guard (almost in unison)

L: guard…(of the) garden *laughs*

R: yes...yes...

L: oh but it can, can't stand…

R: mumbles

OB-Y: if it cannot stand you can also put some sand behind it, it's also ok...like...

R: hey

L: hey

R: hey...huummm…

L: put...usually the Japanese garden sand is very flat...

R: yes I think so...

L: yeah and the...

R: it's not bad...but this should be to the right

L: yeah

R: this one should be disappear…haha

R: and ahhh…I think…

L: ...keep this family

R: I don't know, this is so fat...

L: yeah

R: it should be this...this big

L: just this big

R: yes, hmmm...maybe this one?

L: but it's, yeah

R: try it...maybe...the..the good...eh...like eh, tsuu...to match, match…angle, like like a bri..how to say? Hug? Like hug the small one

OB-Y: hmmm

R: should...should we...I need...here? I don't know, I feel like...it's...like in a lake and the small boat will travel from here

L: ahhh

R: because I've been to a lot of…

L: valley

R: China, china like ahh different lakes and with a lot of mountain in the lakes...so…we just take the boat and then there are lots of situations look like this, a small mountain in the middle.

L: yeah yeah, mhm

R: they will just...

L: ah I see, yeah and maybe, we can broke this micky face

R: yes...yes although they are very close but their cruise is different. Maybe too even? Maybe this should be...yeah...one big one, one small…

L: big valley

R: maybe this one is…this circle is...bigger, let's have a…

L: another, final…

R: yes...aggressive…*laughing*… another aggressive guard here...this one?

L: but maybe these two are…

R: too similar. yeah…ah-ha...so you choose one... *laughing*...

L: maybe...

OB-Y: even if you are looking at the rock and you are thinking something, before you chose it, you can also say what you think?

L: ok

R: ok, like what do we think?

OB-Y: yeah, like when you look at the rock

L: -it's very smooth

OB-Y: what is your opinion of it? Even if you don't choose it

L: ahhhh…this one is some... roof (rough?) one...

R: ahhhh...this is more like a domestic and this is more wild...*laughs*...this one...

L: yeah, *laughing*

OB-Y: domestic and wild? hmm, that's nice, I like that distinction

R: it's like has been smoothed polished by

L: yeah

R: maybe by nature...but it still looks very...

L: maybe down this river...

R: yes...

L: just use this to, smooth this…face

R: I like this surface…

OB-Y: hm

R: unique texture...it should...everyone should see it

L: yeah

R: ohhh its very light...it's lighter than I thought

L: and maybe we can, move this guard to another one...

R: ok...what what you don't like? Oh Its look like a penguin

L: um hm

R: um hm

L & R: *laughing*

R: now I think it, it's cute...

L: yeah, ok

R: but wh...wh...where do you want to put it? or why why you think it's not good...?

L: hmm, but maybe we have to treat of these kind of thing..like this (points to rock), from this unique stone to this...

R: ahhh...ahhh..because this one is...is...ahhh...

L: ah, make it very...

R: ahhh.. It shouldn't let it stol...ahhh...steal his...ahhh...

L: ahhh, presence

R: yes...this, thi...he should be the star *laughing*. Ok...sososo if this is the only one with the light colour maybe we should keep other...like more...mmm without colour…?

L: that one?

R: this one is…

L: um hm, or gray one...

R: yeah..its...mmm...haaa..put others...but I like it this actually...this and this...i don't know about this one...

L: hmm, it looks like the head of some animal

OB-Y: which one? Can you point again?

L: this one

OB-Y: the back one?

L: yeah...it's like a dinosaur?

OB-Y: ohhh, ok I can see

L: why...why we put it here…*laughing*

R: yes...

L: have some...

R: this one-

L: bridge to this

R: pyramid…kind of pyramid

L: pyramid?

R: *explains in Chinese*

L: ahhh

OB-Y: hmm

L: but, hm...this one can also be pyramid

R: what do you think? Should we change it?

L: but I like this kind of vertical and

R: ahhhh for example...

L: how many, how many here...maybe

R: okay...okay...I agree...maybe the back side?I think this is...is..better

L: yeah...maybe, you also have some line to...the dinosaur come back to this pyrami..pyramid, *laughing*, I'm not sure...

R: ok…Do you think we still need anything?

L: mmm...I don't know...should, should we make this...lines more...I don't know (waves hand)

R: yes

L: yeah

R: mmmm, maybe the stone is enough

L: I think stone might be enough

R: ok...

L: and then we can play with this…son...sand

R: ok...should...ohhh...here?

L: yeah, looks like...looks cute

R: yes...

OB-Y: R, why did you pick the small one?

R: because, because eh, still our main... main purpose is try to make this (points at rock) special...

OB-Y: hmm

R: so...now here we have a group

OB-Y: -um hm

R: but without this one, maybe this is still also unique,

L: um hm

R: but if I have, we put a small one here

L: um hm

R: sooo… we can know this two are groups...only he is...this one is

L: unique one

R: a lonely one…

OB-Y: ahhhhh

R: yes…

OB-Y: oh very clever

R & L: *laughing*

OB-Y: sophisticated...*laughing*

R: ww...ww...we are used to this , to do this kind of things...

OB-Y: hmm

R: Ok let's play with the sand...maybe...

L: yeah, should we mix that with...

R: yes...

L: like..

R: yes...lets clear our mind first...it's hard actually

R: maybe if this...ohhh...this is also good to use…

L: ok...can work

R: yes...

L: should we clean all this lines...or?

R: yeah maybe…

L: maybe...hmm

R: let's clean the first...it's not hard to redo it

R: whaa is...feels comfortable too…

L: yeah

R: to do this…

OB-Y: hmm

R: everything comes back to zero…

L: zero degree

R: ahhhh...

L: oh sorry!

L & R: *laughing*

R: so I will put it...OK...wha, like cake…

L: hm and you can...see some

R: yeah

L: layers...to use this

R: can can can we think aaa...a sea...sea wave? Like a beach...

L: ahhh...also we can do...

R: like ahhh...do like this...like

L: do with this ruler

R: yeah it's very straight...

L: um hm, beautiful at first

R: yeah maybe it's...

R: ahhhh so maybe we can make small hills…also with the sand...

L: yeah yeah...to make it…

R: yes...like a different...hmmm...geo...how to say geo geography...

OB-Y: hm

R: do you know what I mean?

OB-Y: like landscape? Geographical landscape

R: yeah landscape yeah yeah

OB-Y: yeah...wh...what made you suddenly think about making the hills?

R: because she is cleaning the sand and you can see some sand gather together to look like landscape...

OB-Y: ahhh *laughing*

R: so maybe it's a good idea ...

L: *mumbles*

R: wow yeah there is also a sand, a hill here...wahhhh…wha it's like older Greece you know

L: hm

R: a...atan?...

OB-Y: hm, like a name of a place?

R: yes...aitan, because they used to build the city. All the most powerful like architecture like the the government on the top of the hill

OB-Y: ahhh, like the acropolis or something?

R: yes yes so people can see everything from the...from there, and maybe usually it's by the sea

L: hmm

R: so..with with...

L: you want to play with this? *laughing*

R: maybe you can make it higher? Can you?

L: to gather…

R: yes, make this...think like this I think this shape is very beautiful...this…

L: hmmm, so can...just go in and...to gather it?

R: yes.this...kind o...I don't know, is that a… now its un-regular shape

L: hmm. It's also funny to have different layers by gathering this

R: yes…

OB-Y: hmmm

L: *laughing*

R: ok...mmm...should...*mummbles*

R: make it ...can can can... we make it higher? No?

L: no, no nigher

R: no? Because now it's just maybe bigger but not higher...

L: do you like it…?

R: yes now it's...high...but should we continue our last...eh...we just give up? The…yes, that's true...

OB-Y: completely fine...

R: completely fine? We just…

OB-Y: just go with the...

R: jump from one to another...

OB-Y: hm

R: ok

L: maybe you can just use it…*laughing*

R: really?

L: sure

R: wow...and huh...and make it flat...oh...wow…

L: yes

R: now we are making 3d model

L: um hm

R: whaa it's good to have sand...to make your...draft mode

L: yeah

R: I think…*laughs*...yes

L: yeah it's soft

OB-Y: *laughing*

R: yes...is it...expensive?

OB-Y: no no no, this is great (thought that R said "excessive")

R: ahhh…I mean I also want to buy it *laughs*

OB-Y: *laughing*

R: maybe we can have stairs…

L: ah

R: ahh...it's like eh…

L: like eh

R: Tibet...like Tibet.

L: Tibet?

R: Tibet! *speaks chinese*

L: *laughs* *speaks chinese* ahhh...

R: palace of…

L: palace of-

R: how to say then...do you know Tibet?

OB-Y: yeah

R: do you know there is a very famous palace...

OB-Y: oh, I don't know but I think I know what you mean like the temples?

L: um

R: yes..yeah...temple...yeah...but this stairs is not...not obvious…

L: um hm

R: but then we have our...ehhh...now it's sacred…

L: *laughing* yeah

R: they have…have extraordinary status…

L: *laughing* yeah

R: yes...but still this one is...yeah its ehhh...co-, like people from nowhere...but

L: um hm

R: ahh… it's still very…eh…outstanding...challenge the...

L: yeah...it's like the road, then people will go up to this palace, but people will go by this road can see this kind of-

R: yes…yes...different view…

L: structure

R: do we have? Do...do...do we need this one here?

L: hmmm

R: no may...may...maybe then we...if have ahh...division here…

L: um-hm

R: mmm...this...should be maybe a little more…

L: here?

R: yes this way or...or we should change it

L: hmmm

R: but actually I like this gr-...this

L: yes

R: composition, I want to take a picture of this, is it ok?

OB-Y: yes sure of course

L: it's kind of the garden of the palace

R: and...I...I think these three make a good match...

L: um hm, yeah, (I) like it

OB-Y: can you try to talk a little bit about each of the parts of your design?

L: parts? Ahhh...but we changed a lot

OB-Y: I mean...ah what it means for you...

R: ahhh means...yeah

OB-Y: I feel these is some meaning

R: yes

L: um hm

OB-Y: to these things… some of it I know...

L & R: um hm

OB-Y: ahhh like like that one which is standing who is unique...

R: yes

OB-Y: but how about the other ones or in general what do you think about each part?

R: maybe...I..I...think this one represents the...power...people who has power like emperors...something...

OB-Y: hm

R: and this maybe his follower…*laughs*

OB-Y: ahhh

L: *laughing*

R: *laughing* no...yes...but this one is key...maybe he grows in a like normal family but he is very unique

L: talented...

R: yeah...talented…so...

L: *laughing* to challenge this…(points at the rightmost rocks)

R: yes…

OB-Y: hmm

R: and this…I don't know this one...because it remains from the last design...

OB-Y: hmm

L: maybe common family

OB-Y: it's OK

R: common...yeah...it's too big to be common family

L: um hm

R: if…if...they can represent…

L: like the middle of this…

R: yes…

L: or...maybe it's...

R: na...no…because now it look like they are protecting them…(two back rocks protecting the front central arrangement)

L: um hm

R: but they are...they are not so unique…

L: maybe just looks like other...other...that were common people...and the...they are very are talented...

R: hmmm

L: ones...and the government to...our back to...support us…?

R: yes…*laughing*

L: I'm not sure…

R: *laughing*

OB-Y: hmmm...it's actually very interesting…

R: I really think it look like a...

L: um hm

R: the...because of the the...the shape of this stone…

L: um hm

R: it look like it was flushed by the water…

L: ahhh…

R: so…

L: you still want a river…*laughing*

R: yeah...it's really like...like flushed by the lake water…so...so...I think that's why looks so harmony

L: ah

R: because it's...it's a...ahh follows the nature's rule

L: um hm yeah

R: look like a real, real

L: view

R: view in the...in the real wor...real world...I think that's why we like it…

L: and maybe in this people view

R: yes…

L: you can just see this kind of valley

R: yeah...should we have a...have a boat?

L: *laughing*

R: no?

L: what kind of boat? *laughs*

R: no they are too big for...

L: ahhh…

R: these are too big to represent a boat…

L: um hm

R: I don't' know...don't forget about the...how to say? As...asm...asmatic…

OB-Y: aesthetic?

R: aesthetic...the beu...beautiful

OB-Y: yeah aesthetic…

R: aesthetic, yes… let's focus on the aesthetic part as well…

L: um hm, yeah

R: I think…this one should be...if we…

L: um hm

R: I don't know…now we, we are doing everything from, from this side right?

L: yeah...

R: so...can we see we have a fron...frona...frontality? *laughing*

L: *laughing* and the road is very...

R: straight…

L: yes

R: maybe we can make it more nature...natural right... a good big curve

L: hmm

R...and a...

L: the road too big *laughing*

R: yeah...then use your...your tool…this...this tool…

L: should I use that?

R: is that the river? If is that…it's so wide…

L: ah, it looks like a river

R: yes it's like a river...

L: but...we can have a river, right?

R: yes…

L: just like two side...

R: yes

L: two side of this...

R: wow...you...ahhh...so...so…

L: the island (points to back right rocks)

R: then maybe this should be the sea, because usually the...the...the palace, the temple is...

L: um hm, face to the-

R: the palace, yes it's very high and maybe this side should be a cliff or something?

L: um hm

R: the river goes to the sea

L: yeah

R: yes...

L: *mumbles* try here...

R: yes...so this is the coast

L: um hm

R: if this is the coast...shou...I'm thinking of a lot of trees here...

L: trees (confirming)

R: but we don't have trees…

L: ahhh

R: yes...if it is urban planning I think now we need some trees here…*laughs*

OB-Y: *laughing*

L: hmm

R: yes…

L: maybe some...small plants…ahhh...not sure...to have-

R: ah just patterns…

L: maybe patterns...

R: oh! oh patterns...then...I…*mumbles*...oh this is...trees only from the plan...no?

L: hm

R: no...we are not drawing a plan. OK…that's the trees. Should we do anything else? I still don't know what they are...representing for…

L: mmm...I like it former one…

R: ahhh

L: like it has some value here...and this one is just to protect this...

R: what? What? The former…

L: this big one too, like some protecting the little

R: small one

L: small ones

OB-Y: hmmm...

R: hmmm...yes

L: and they all protect this one...looks like…

R: yes...that makes sense also…but...

L: *speaks foreign language*

R: but why they are so important...so so this represent the children and they are their parents...so they are like *mumbles*

L: government

R: governors

L & R: *laughing hard*

L: *speaks foreign language*

R: ohhh

L: don't like...i don't want to make it very political...

R: yes… *laughing*

OB-Y: *laughing*

R: Yes...but it's a...makes sense then…

L: *laughing*

R: ah I can't, oh my god...ohhh

L: *laughing*

R: oh yeah

L: like a…

R: ok. We tried this...so maybe we can change...change for another, so this is a family, ok?

L: ok

R: *laughing*, because you like it…

L: *laughs*

OB-Y: so you are considering a different option for that place?

R: yes...

{2nd Composition, 33:09}

L: should we...

R: yes...because... once we remove them we can think more open

L: um hm

OB-Y: ahhh yeah

R: yes… and...sh...

L: but this kind of higher place also sym...bolitic (wants to say symbolic)

R: yes...

R: maybe we can

L: maybe

R: yes...it's the one thought...

L: *laughing*

R: yeah ...it's too specific...

R: uh huh

R: we had fun so let's, let it go...? *laughing* oh ohhh...but it's it' s...do we have a topic like Zen garden or something?

OB-Y: you don't have to do that

R: ahhh...ohhh ok...ohhh

L: but I…like here (points at the remaining rock)

R: yes…so...so this one is our main character right?

L: yeah…*laughing*

R: *laughing*

L: from the beginning

R: ok...ok…ok...it's really thick…

L: uh huh

R: this side…oh my god...this one...just just this one...eh...eh...eh…

L: *mumbles* flat it (make it flat)

R: yes...flat it...ah yes we have this...ohhhh...really...wahhh...wahhh...so comfortable

L: it's like omochi (Japanese sticky rice sweets)

R: mochi? *laughing*

L: omochi

R: yes…also like the cake…did you see the video of making cakes?

L: uh, yeah yeah yeah

R: It's really fun...but I don't know how to make a cake...

L: *giggles* yeah

R: ohhh also like a a you paint your wall

L: ahhhh I see...

R: with the...how to say? *speaks Chinese*...

L: um hm

R: it the…

L: the roller

R: mmm...so what do we do now?

L: maybe this corner and then another...

R: can you draw some very abstract line?

L: mm

R: like...modrin...mo...mo…mo...mondrin (means Mondrian)

L: ah Mondrin...

OB-Y: Mondrian?

R: Mondrian?

L: Mondrian

R: yes...yes…

L: so then may not need a stones for just maybe…? (hand gesture)

R: this...here...can be…a short one?...this…

L: I like it...

R: yeah...because we-

L: it's like also...

R: we, because...after the...re-...how to say? the...removed?

L: flat it?

R: yeah...after we rearranged the sand we-

L: uh huh

R: I saw some, like this lines remains…

L: ah-ha

R: so I think maybe it's cool to have...

L: yeah, this constru...construct

R: yes...

L: construct

R: make it flat...

L: um hm...just uh...

R: sh-...just a remain this one line maybe…

L: yeah yeah yeah, um hm

R: is...is…*mumbles*...no...they are too sensitive...

L: *laughing*

OB-Y: it's no so easy

L & R: yes

OB-Y: not so simple

R: ehhhh...it's very easy to a...remain some...how to say? trace...

OB-Y: yeah, yeah! Some...some holes

R: yes…

L: do we need to extend this line? With more...

R: extend? This line? I don't know...

L: maybe

R: because we already have a very long line here…

L: ummm...from here?

R: do you think if we have another one...ahhh...Mondrian…

L: the back mo…mmm...because it's not very strong?

R: ...mm...maybe...

L: or just-

R: like...how to say...Mies van der Rohe? (famous architect)

L: *laughing*

OB-Y: hmmm

R: but...then...

L: ahhh

R: they have...this one (adds a line) do you remember?

L: yeah...

R: very famous plan...this one...

L: um hm, ah I see

L & R: *laughing*

L: have some

R: and...he...here...right...this one right...ahh…

L: yeah

R: and then we u-

L: close to the river

R: yeah...and we can...mmm…use the stones to represent the colour maybe…

L: hmm

R: in the…original drawing

L: ahh I see

R: ...they use different colour to...I don't know what is the colour...yellow or red?

L: hmmm…

R: sss...so difficult...ok…

L: maybe some stone...

R: yes…

L: *laughing*

R: yeah...we...are playing...playing chess…

L & R: *laughing*

L: yeah...

R: you…you like the stone on the line or in the grid? (inside the grid cell) you...li...you prefer on the outside?

L: we can try...

R: yes...and a…

L: and we can…

R: I thought we...can-

L: hmm...it's good (speaks to herself)

R: make it like in the middle or something...

L: ok

R: in the...but maybe not this...stone…maybe just...

L: maybe the f...

R: I prefer more

L: round?

R: how to say...good behaving…

L: *laughing*

R: more...eh (discovery)...maybe...yeah maybe this small cute...noo…its too small!

L: *laughing*

R: it's too small…

L: ummm

R: a little bigger...mmm...this one? But this a little

L & R: too big (in unison)

R: for the...grid

L: um hm

R: for this...this is also too small…right?

L: yeah

R: and I think it's too...this side...this…(points) is too small...

L: um hm

R: if it looks like one…

L: ahhh

R: this...I...I think it's ok. Maybe let this stand…stand…

L: ahhh...oh!

R: I don't know, like small...very small...ah!

L: very small (want to say smaller than) this one (points)

R: ahhhhhh...the...they are bothers...they are sisters

L: yeah

R: but...the...in different scale…*laughing*

L: *laughing*

R: it's too small...may we can have...several of this...(points)

L: ohhh

R: like small hills…

L: yeah

R: I like this one maybe...

L: I like this one

R: this one...maybe...here...yes...

L: um hm

R: yes...tha...that's a...another…

L: *whispers* line

R: yes here...a...but maybe here should be...eh…what...ehh...maybe...just leave it. Here or here? here?

L: hmm, should we put it vertical? or...

R: I think...ah…

L: ohhh

R: I think maybe we can do a series that...all-

L: um hm

R: they're all standing

L: ah I see

R: yes...like this is...a...small..smallest (points)

L: ahh...li...likes animal shouting...she is shouting to hill

Y & R: *laughing*

R: yes ah...like bear...yeah

L: oh...the higher (points)…*laughing*

R: yeah also... like seal…

L: yeah

OB-Y: which one?

L+R: this one…(pointing)

OB-Y: ahhh

R: not...he is not cool...he is just...cu...cute...

L: cute

OB-Y: *laughing*

R: no I dont like he ...he be cute, he should be cool…

L: yeahhh

OB-Y: *laughing*

R: wah... so this is very...kind of evil I think…

L: um hm

R: don't you think so? Its like a..

L: it's like a...very...shape…(wants to say sharp)

R: yeah... sharp

OB-Y: can you show to the camera?

R: its where…*mumbles* like a...a...once you are very kind people but eh...evil witch took your heart out and then put it in the...

L: in the…

R: ...in the poison…

OB-Y: ahhh

R: and then your heart become very hard and poison, how to say?

OB-Y: hm

R: With poison…*laughing*

L: um hm *laughing*

R: the kind of...sttt...very dead...dead-ly…(want to say deadly)

L: devil

OB-Y: hm

R: dead like...dead weapon…

OB-Y: hm, ahh

L & R: *laughing*

R: but it's too big...maybe...he...this one should...do, or do we...which one is better?

L: ahhh (topples rock by accident)

R: the color... this one is better...right?

L: yeah, the colour...is...yes...

R: yeah...this is too big...for...for...for anywhere..maybe here? hmm...

L: hm

R: maybe now...we...we need...eh...kind of ah...balance…

L: yeah

R: this is...

L: maybe here?

R: here...mm...this one...we need to...eh...why it's not...

L: behind this...line

R: behind this line?

L: beside this line

R: oh…eh...wah...

L: it looks like three stones to...want to attack this (points)

R: *laughing*...no...no they are...supposed to be like a sequence...

L: no...harmony…*laughing*

R: they ...they are the same species… wah...

L: maybe more...(places a rock)

R: *laughing* ohhhh...

L: *laughing* it looks really strange

R: ohhh this one is...so un-harmony…*laughing*

L: *laughing*

R: ohhh...no...

L: like monster *laughing*

R: yes monster…no…you leave…

L: *laughing*

R: yeah…we can have a...a..anoth...let..let...it on...another series, no not this one...this one may...maybe you can keep pure..

L: ahh

R: yes...just a…very...do we need more lines?

L: hmmm, maybe…

R: I don't know... mm...make it…

L: straight and a...pure

R: to..to..to..the...to the end-

L: can try...

R: this is too much…? oy...

L: hm

R: eh, I don't know...no but it not p-...it's...at the end...do it well...ohh...eh...the lines before is more beautiful…it's so hard to-

L: yeah

R: -make things beautiful…

L: maybe also this one-

R: it's hard to add anything after...like eh...when when a design is finished

L: um hm

R: is almost finished...it's the most difficult period…

L: yeah

R: it's so hard to add anything...

OB-Y: umm, right

L: (places a rock) *giggles*

R: mm...it's too even...

L: maybe...maybe we have some group, cross this one?

R: but…

L: um hm

R: mm..but there...you, you want this group to be...different? Because this one is very difficul- eh- different from others...

L: yeah...yeah maybe...vertical one

R: this one is very similar to this one…

L: um hm, ahhh yeah

R: maybe next time we can have them…

L: yeah. Maybe this kind of vertical?

R: yes vertical, yeah it's very unique…oh...wah...*laughing*

L: *laughing* like the bird's house (points)

R: eh...this...like some gear...ohh...where, where should we put it?

L: umm

R: ooh, I...I...I still think there is one spot here left...is here...

L: um hm

R: like from the layout...I mean...

L: keep it empty?

R: empty is also ok, but something smaller than this I think...yeah this is...you...do you want to put it before but in a horizontal position?

L: yeah

R: I think this is maybe it's fine if we keep it stand...

L: yeah

R: th...they...they some kind of...making some magic things here…*laughing*

L: *laughing* like a-

R: we can have a circle...

L: like a circle *laughing*

R: yes…yes…

L: have some magic

R: yes...yeah...then we can...yeah…*mumbles*... oh yeah...maybe they...are...

L: the center

R: yeah this is...the...

L: ohh

R: I don't know...

L: but maybe in this kind of situation...this one can be the centre…

R: ahhh...but...mm…maybe...as long as…you know...sometimes...the most...like a...mm…Maybe they are...this one is...how to say...ancestor or teacher...are these are siblings...

L: um hm

R: but this one is the most...this is the best one...so...they...eh...I don't know...

L: *laughing*

R: maybe this one...this way...this way is...

L: yeah yeah yeah I like this way

R: and...but...we can keep the...the...the...the square...a...

L: square

R: how to...so difficult...to draw some- draw anything...ohhh...wah...no I failed...

L: *laughing*

R: it's so difficult!

OB-Y: oh it's ok it doesn't have to be perfect as long as it shows your idea

R: ah...ok...I'm not good at (making a) model actually…*laughing*

OB-Y: *laughing* good enough

L: *laughing*

R: ohhh...I think you are very good at model...

L: hmm...no *laughing*

R: right…

L: look like flowers *laughing*...nooo

R: ok...lets remove it...remove it…

L: yeah

R: ok…

L: maybe...hmm

R: mm? do you want...do you like it?

L: nah nah nah, you can move it *laughing*

R: *laughing*…ok...

L: oh can have some...you know some...these precious two

R: oh...

L: keep the…

R: so...so...so...so this are the...eh...like...they...like the evidence this one been here?

L: yeah yeah yeah like this

R: *laughing* that (is like) traces...

L: yeah

R: wah maybe...yeah...and there...there...this the shape of the holes are so different because they have different size and texture…

L: yeah

R: yes...its good… yeah...that will be fine...

L: but there's some…*inaudible* may not be represented very well...

R: mmm...maybe it's...it's this side...

L: ahhh this side

R: yes…

L: but still very smooth, not...can you show this shape?

R: maybe you can try the very thick...place...yeah...

L: ahhh

R: yes, you can see its very sharp...

L: um hm, down (places rock upside down)

R: *laughing* ohh upside down...eh, no? a...this two are so very similar you see...

L: um yeah, oh look like the section of some blue diamond *laughing*

R: yes

L: but it actually look good

R: I think it look like liver... *laughing*

L: *laughing* ok

R: ohh goose liver or duck liver…*laughing*

L & R: *laughing*

L: maybe...

R: oh, yeah we have some, actually we have several...this section...

L: um yeah

R: we can show it...

L: kind of small

R: yeah...

L: this one is also...small

R: and bury other part...only show the...section

L: yes, yeah…

R: eh, sorry, eh no...you're out…*laughing*

L: *laughing*

R: eh...bury the…*laughing*

L: ahhh I see, to cover it?

R: oh, I don't know it's look like they are sleeping…*laughing*

L: *laughing* oh looks like in the car

R: car?

L: coff, ehhh sleep in the coff

R: a coff? Oh no! (wants to say coffin)

L: yeah...

R: where is the section? Oh

L: yeah

R: the domestic one...

L: um hm, too *mumbles* to make the sand *inaudible*

R: ohhh you lea...mm...you know...wah…look like a...like a...like how to say? Wild people, they live in the cave

L: ohh

R: so this is...the…entrance of their cave...

L: ahhh

R: so their living space is underground...some kind of

L: um

R: do...do you remember...Inna's design...

L: ahh I see *mumbles*

R: yes yes...I see but this is too high?

L: this one? Maybe just...this one also out

OB-Y: I don't know how much time you have (to spend) but we are already one hour...

R: ohh...really???

L: one hour?? *laughing*

OB-Y: I didn't want to tell you because uhh, I saw you were really you know, deep into the activity...

R: ah...I really don't know...i thought...a...I...was...wondering eh maybe it's 30 minutes but...I...am not sure but since you didn't tell me, I think maybe 28 minutes…

OB-Y: ah really? Ok I'm happy *laughing*

L: 'cause we changed the…*laughing*

R: really? Oh yes, but I like one

OB-Y: If you want to finish this one, it's ok. I'm personally not in a hurry, depends on you.

L: um hm

R: *laughing* it's not beautiful at all but I think it's interesting

OB-Y: um

L: yeah...this one...

R: no...no this one...this one

L: very rough...ok just use hands to make some…

R: yeah, it's really like a...how to say, a tribe...a wild people's tribe, they separate their houses in different places, but they...

L: ah...

R: they can gather together sometimes...

L: yes

R: yesss…

L: yeah

R: maybe it's in a very...very very cold place like snow hills…

L: um hm

R: around them...

L: ah - yeah

R: they only have...a...

L: oh yes...looks like snow

R: yes...very interesting...this one…

OB-Y: hm

L: yeah

R: mm...

L: nice...

R: it...it's...it's actually, I think it's good it's interesting to sometimes have this kind of experience by yourself even..

OB-Y: hm

R: to have you more...open your mind have more very, how to say? very different...

L & OB-Y: inspirations (In unison)

R: Inspirations from...from your daily design…

L: um hm

R: you usually have your tasks...

OB-Y: yeah

L: yeah

R: you have your goal…

OB-Y: yeah

R: it should aim to something, but now you can discover...yeah...

L: just *inaudible* *laughing*

R: some deeper design...or...inspiration in your mind

OB-Y: yeah yeah I think you had a lot of ideas

R: really? *laughing*

L: *laughing*

OB-Y: in this session, yeah! I kept track...quite a lot

L: ohhh

R: ohhh

OB-Y: I was wondering, I have some small question, to understand what was going on. So, in the beginning, the first thing you said is "I want to make a corner garden"

R: yeah...

L: um hm

OB-Y: so I was wondering where did that come from...

L & R: *laughing*

R: oh, oh...because I thought the...the...we are going to make a Zen garden

L: um hm

OB-Y: hmm

R: and actually I thought...eh...first sight of this stones...I thought maybe this stones are not enough...

OB-Y: hm...

R: because I want to use the stones to make a real…

OB-Y: yeah

R: real garden

L: ahhh, this path

R: yeah, and a maybe have a...have some...shapes…

OB-Y: um hm

R: or something...like like this...

L: um hm

R: and then...she changed my mind

OB-Y: um

R: because...she she "jah! pow!" (makes sounds and gestures of energetically placing the rocks in the garden)

L: *lauhging*

R: put a very unique...stone here...so I "oh ok yeah it's also a good way to..."

OB-Y: um

R: exp...how to say? expand...

OB-Y: yeah

L: just remind of the Japanese

R: ahhh

L: culture…

OB-Y: so before you said it, you though you are going to make a Japanese garden...

R: yes

OB-Y: ah and then you said this rock is

L: um hm

OB-Y: beautiful, or something like that? hm

R: yeah, yeah because I...I saw the stone stands here

OB-Y: um hm

R: and umm, oh, it's totally different from what I was thinking in my mind...the picture is totally different...but I…I'm open, usually I'm open to some new ideas so I take it, accept it and then I follow his...her, her mind…

OB-Y: ahhhh

L: *laughing*, really?

R: and then I...yeah...and I changed my mind like one second

L & R: *laughing*

R: like ok...let's forget that...I...I…

L: *laughing* try...

OB-Y: it was quite fast...hehe...

R: *laughing* yeah!

OB-Y: yeah, it...it was very flexible

L: yeah yeah yeah yeah

R: yeah, I'm very flexible at the...at the beginning...

OB-Y: um

L: this material is very flexible…

R: yeah maybe yeah

OB-Y: ahhhh

R: because it can represent a lot of things

L: yeah

OB-Y: hm that's true, and also can easily be changed

L & R: yes

OB-Y: you don't have to do anything just move...so...so...

L: um hm

R: ye...yeah you don't have...you don’t need to ex...how to say...take your times or money to change anything, so you won't hesitate to do it...

OB-Y: right, right. Ohhh, that was very nice. And, you mentioned something about science fiction, a series or movie.

R: yeah yeah yeah

OB-Y: so do you know the name?

R: yeah I can show the picture

OB-Y: ok, ok!

R: It's quite cool, I will show you the scene I was mention...

OB-Y: and L, for you um...what was the most ahhh...like the composition you like the most

L: ahhh

OB-Y: from this activity, do you remember?

L: maybe...maybe the unique one here and have some groups here (points)

OB-Y: ahhh...

R: the first one *laughing*

L: *laughing* the first one!

R: yeah

L: because I just like this stone very well (much)

OB-Y: ahhhhh

L: and I just want it to be very unique...the topic the star here. And we also have this groups to make it uh, to be this home-, how to say? The harmonies

OB-Y: hmmm

L: to yeah...to cooperate this one

OB-Y: ah, somehow to support that rock...

R: yeah yeah yeah yeah

OB-Y: hmm

R: L? oh my phone died,

L: oh

R: expense, the English name is expense…(the name of the science fiction series)

OB-Y: expense? Ah sure, no problem. And one last thing, do you have the picture that you took of the 3 rocks in the middle? Like one one and small one

R: yeah my phone died

OB-Y: its ok, if you remember its ok

R: yeah yeah yeah I remember

OB-Y: so at some point in the beginning, I think R said its kind of, like there is water around it

R: yeah

L: um hm

OB-Y: and later, what what happened to that? Did the water disappear or…? like we had a hill, after that there was a hill, and there was a rock on the hill and the three rocks, then you said they are like a family or something like that.

L: um hm

R: hmm

OB-Y: so at that point. what did you think about the...

R: river?

OB-Y: yeah.

R: I think I just, the river

OB-Y: um

R: yeah at first I said it looks like a river

OB-Y: um

R: but also it looks like hug

OB-Y: um

R: so sometimes if you are in the lake you can see oh these 3 mountains look like a family

OB-Y: um

R: so they can be river...like mountains in the river...also, they can look like a family, so they can be two things at the same time...

OB-Y: ahhh

R: so sometimes I took one meaning, sometimes I take another meaning

OB-Y: ahhh

R: and with different context, I, my mind will prefer this in some different ways..

L: *giggles*

OB-Y: um, what did you think about those rocks? like when you imagine the environment around them or something, is it for you also like or something different?

L: the rocks ummm, but also we also use this some kind of device to...to flat this sand

OB-Y: hmmmm

L: and I think it also can be one part of this. And when we...flat this sand, and you can see just this stones can play his roles in this kind of position, and how it corr-, correspond to the sand behind, behind by we doing...by use this to sand

OB-Y: ahhhh, yeah I saw that the sand had a lot of effect actually, on the design process

A.4.5
{1st composition}

OB-Y: ok we can start. And sometimes I will stop you and ask some question, if you don't have an answer just say "I don't know"

K: ok so…

M &K: ok *laughing*

OB-Y: you don't have to answer anything, just if…if you feel like "I don't know", you just say "I don't know"

K: um ok

M: ok

K: so we need to design the garden, so how should we decide (the) concept? *laughing*

M: *laughing*

K: I fell like maybe…put the bigger stone could be easier to design…all..garden, so maybe I put this one to here, this is just random

M: um hm

K: do you have any inspiration? *laughing* maybe this way could be better *lughing*. I like rock with, not like round one, like a sharp

M: um hm

K: rocks with sharp edge, so maybe I can use, I can put this one
like…here…here…hmm…like this…*laughing*

M: likes…like trees

K: *laughing*

OB-Y: M what are you thinking when you look at it?

M: mmm, I think just like some uh, totally structure, decide to point at the first, and the small stones can (be) dedicated to more detailed uhhh…*mumbles*…some other decoration, I think

K: um hm

M: but I…look forward to (the) next step

OB-Y: ahhh

K: so…what I think is that just put a lot of stones, like randomly,

M: yeah

K: then maybe we can fix it

M: umm

K: you know..just put stone like here and like here

M: cool

K: then like "uhh, maybe this is not here", you know? *laughing*

K: *laughing* maybe we can just do…do designing and fix it. I don't like this stone so…(removes stone) *laughing*

M: *laughing* catching another one...

K: um hm

M: would you like this one?

K: yeah just…put…your favorite stone to…your favorite place

M: ohhh, ah, we are…we are doing together? ah sorry sorry!

K: yeah yeah the same …

OB-Y: yeah, totally

M: I thought it's one by one

K: no no no

Y: ohh it's ok

M: um, I think, um the most important point for a garden is the…the…or how to say? I some loop, the high and down and high

K: uh huh uh huh

M: so…but this one is a little low, this one is a middle one, and this is a small one

K: um

M: so, if let me decide the best way I..I..I maybe I can like this one

K: yeah yeah yeah

M: to…sorry I'm not really good at this designing, but this way

K: oh! *laughing*

M: and this way view…(hand gesture of wave, voice tone matches hand movement)

K: um hm

M: and...

K:I think the...we have two or three kind of colours, this is more like a..gre....grey..

M: yes

K: and this is more dark, so maybe we can make gradation of colours?

M: yeah

K: so I think...this one?

M: yes, the same color

K: yeah and this is...little unique so...maybe put this…*laughing*

M: *laughing*

K: this is difficult...this is you know, what I don't like about this stone is this is little round….so...maybe…use this way...mm...I don't...maybe like here...

M:um, I-

K: I don't feel this is a... right place..

M: umm, *laughing*. And next way is, this two corner is quite empty

K: um-hm, um-hm.

M: so I'm...I think about how to relate these two parts

K: um-hm.

M: so this way...maybe because it is a garden we have some roads...

K: yeah...yeah...yeah...yeah...

M: and this is the yellow part, this is the grey part

K: mmm…um-hm

M: so how to...connect, how to connect this two parts, it's the most important I think...so..

K: yeah yeah yeah yeah

M: mm…and the…ah…this stone is the same color

K:um-hm

M: so to...change uhh let me s...so...*mumbles*

K: mmm

M: I I don't know if it is a good idea but…yeah? Ummm I don't like this

K: *laughing*

M: uhhh

K: I think...ah...what I think is ah...like ah...a blank space is also important...I think….

M: ah yeah, maybe yes

K: they have, yeah, that kind of beauty so maybe...for some reason...I don't really like these stone...so I put this here then...

M: hmm

K: maybe small one can be here

M: it's better I think

K: yeah

M: hmm...then...

K: maybe we can put ehhh...more stone here...then like this side have more stone and this is little less stone (hand gestures)

M: to illustrate this parts (hand gesture)

K: yes yes yes…

M: ahh I see I see. Is it better to...make this part more colorful?

K: ahhhh...maybe...maybe

M: let me see...

K: um-hm

M: this way?

K: um-hm

M: to make this more colorful...this one...

K: um-hm

M: a little umm...simple. Then, more groove (hand gesture), hmm...

K: I like relations of these three stones...I think...

M: ah so cute *laughing*

K: yeah this is...good...

M: and uhhh

K: yeah I also agree with you the height is very important to designing garden, so...I wish we have more like stones with hay...height...

M: um hm, ok

K: maybe...

M: we can try it

K: yeah but its very...little hard to…make it stand

M: *laughing*

K: umm

M: umm

K: do you like this one?

M: um, how about to make this parts a little...um have some stones?

K: yeah yeah yeah

M: like this one is still empty, so we can have some difficult umm scene, scenery

K: um-hm...I think a small stone could be…

M: oh yeah I think so

K: yeah yeah

M: yes

K: better to...um...I'm, my idea is to ex...exaggerate this height, maybe we can put the more like a low stones to emphasize this height

M: ahhh, ah I see!

K: maybe...

M: so from this scenery we can...we cannot see the stones, but from this scenery we can see...

K: um-hm

M: there's difficult (wants to say different) feelings to some travelers, I think

K: mmm-hmmm...

M: uhhh...and how about this scenery or this scenery? (shows directions with hand gesture) We can put the four...the four see point (viewpoints), make it realy diffic...different.

K: um-hm I...eh...I have a little...a…*speaks Japanese*

M: *speaks Japanese* yeah yeah yeah

OB-Y: Ah…

K: a strange

Y: like inconvenient

M: yes

K: yeah inconvenience between thi...this distance...between this...this two stones, I don't feel this is (the) right position but I don't know how to fix it...

M: you can hide...hide some...umm… *speaks Japanese* *laughing*

K: *laughing*

M: some parts of stones...yes

K: mm...yeah. I think we are designing good...garden

M & K: *laughing*

K: I kind of like it...umm

M: I think it's enough, and we have some wave

K: ah yeah…yeah is that ok to make some pattern? *laughing*

OB-Y: yeah it's ok.

M & K: *laughing*

M: Japanese travel (wants to say gravel)...it's traditional (hand gesture)

OB-Y: basically...

K: oh yeah *laughing*

OB-Y: we...we only analyze the, the rocks usually...

M: wah...

K: *laughing*

OB-Y: but you can make patterns if you want, to show the...how you imagine the design

M: wah yeah yeah this way...yes

OB-Y: oh nice, it's quite gentle...

K: and this is very difficult to...make patterns

OB-Y: mmm...not so easy, looks easier...

K: *laughing* I think we have enough stones to...we have enough stone here...

M: *laughing* you're better than me...and this way we can connect these parts

K: um-hm

M: and this way...it's like water *laughing*

K: ah...maybe we can finish this...uhh garden for...for now, maybe we can make another...designing pattern? Maybe? Or should we continue to design this pattern?

M: I think we have completed nine...ninety percent

K: uh-huh, ohh...we have ten more percent

M: yeah…hmmm…it's nice garden I think, enough

K: yeah I think this is...enough. If we put-

M: yeah...

K: too many stones it could be too much, maybe we can finish it

OB-Y: ok...

K: ok

M: um...

OB-Y: yeah…that's the first one

{2nd composition, 12:12}

OB-Y: ok we can start the second one.

M: only three?

OB-Y: maximum three

M: maximum thee?

OB-Y: maybe second one (2nd session) is uhh...is enough

M: oh oh, I...I...I...I...I think...I mean, this three stone?

K: no,no,no...

OB-Y: as many ask you like...

M: ah ok, ok…hmmm

K: so for second pattern I would like to try as many as

M: yeah rocks.

K: many many rocks

M: ok, ok.

K: so...

M: the first one is...mmm...what's the structure?

K: mmm

M: this this time...because...

K: um hm

M: the last time is is this (hand gesture)...and middle and small numbers of stone and this is empty one…(hand gesture)

K: um hm

M: and we can...we can change some concept about the garden

K: yeah yeah

M: cause the last time is Japanese traditional garden

K: um hm

M: how...what if...some some western...western styles...

K: ah yeah yeah yeah sure

M: It just my idea...

K: um hm, so western style garden means like a...we have like a...umm passage here

M: yeah...

K: and here...more like we see the patterns...

M: yeah I think so

K: ok

M: so...can I can I start?

K: yes yes please

M: so it's a western stone…?

K: um hm

M: western this one is point...ahh so ugly…

M & K: *laughing*

M: wah...anyway anyway...we can change

K: um hm

M: and...we can some…*laughing*, it's ugly...but but we I I I...

K: and just...do it and we can fix it...

M: we can change change uhhh next time...

K: yes...

M: this three

K: um hm

M: and if...I...I...I...I think it is um...spring, mountain, fa...fa...fountains…yes..

K: fountain? Ok, ah I see I see

M: and this way is the main road

K: um hm

M: and we can we can fit some...colorful scenery for this part, this part, this part.

K: um hm

M: and we...we...don't need to connect each other… I think…

K: um hm, ok. So...maybe this could be...this should be...like a...really middle of this square, the center

M: yeah yeah

K: on the centroid. Then...ok soo...this part is more like uh uh, towers...

M: um-hm

K: and sooo…we can...put...uhhh, four...like...I'm thinking putting put four stones

M: mm…

K: here...it could be something

M: um-hm

K: this is totally random

M: *laughing* yeah...

K: so I'm not sure this is right...but, this could be one area

M: hm-hm

K: this, so we can divide these space into four...

M: um-hm yeah

K: part...

M: so...

K: umm, maybe we can put, ummm, yellow stone here, so yellow part? (hand gesture)

M: yeah ah...ok.

K: this could be yellow part

M: and now assume this one, this part is the main building

K: um hm

M: so...the lountain…the fountain is here...this one?

K: oh like castle?

M: yes yes

K: maybe you can use this big stone…

M: oh yeah maybe it's better… this one?

K: do you think this could be…like here?

M: ah yeah, *laughing*...and...this...zig zag...

K: we need something here right?

M: yeah I think so...I think this part is always yellow...yellow color…

K: um hm

M: so… if...mm...I want to make this, this part more colorful

K: um hm

M: because mm...yeah so more colorful one...

K: so for more colors we can use maybe...this kind of stone. Because, these stones have two colors.

M: ahh...

K: But this, I think this is too big...to...

M: yes

K: yeah so...I'm using this medium size...

M: um hm… wah its better…

K: yeah.

M: this part is also...bl...blue one…

K: um hm

M: chose one more yer...yellow...yellow stones…

K: um hm

M: and to...um…tower...

M & K: *laughing*

M: no no no no no...tower...*laughing*....it's funny...

OB-Y: *laughing*

K: so maybe...we can put ehh, so I think what we need to do is making a concept

M: yeah yeah yeah

K: to this space...

M: yeah

K: ummmm…I think...

M: mm

K: this is the main part (hand gesture of grouping), so I think uh the...each part should be open to this side (hand gesture towards right)

M: oh...yes...

K: so I think we have a height in this, this side

M: um

K: so maybe we can move the stones to like...like this...so...they can make more open image to

M: ahhh, I...I see

K: this side…

M: so...the same as this part?

K: ahh I think…those parts are...so maybe we should make this part with low stones...?

M: uhh, low stones yeahhh, oh maybe it's better...I see, yeah yeah

K: yeah so I think this could be right here so we can have more open side from this side?

M: and thi-, this part is narrow one

K: mm

M: and and then when people walk to this part (points)...and the scenery...can open suddenly

K: um hm

M: and this one is more narrow...

K: ummm

M: I think it's some mmm...rhythm…

K: um hm

M: so this this...thi...this part can, can make some scenery...

K: yeah sure

M: small one

K : um hm

M: first I...I want to decide the point...

K: um hm

M: so...cause this one is...mm...a little low so...how about to make some...the this the same frame but more small one..

K: um hm

M: hmmm ugly…*laughing*

K: no no...I think this stone looks similar with this stone so..

M: um um

K: I think they can match so I would like to put this stone here...ummm

M: yes then we...then we obtain...the y and x (axes)

K: hm um

M: it's nice...

K: ahh...maybe we can put a...ummm...I thought maybe we can put the east wing, west wing but

M: ah yes yes

M & K: *laughing*

K: but…

M: eh like castle! *laughing*

K: yeah but this is not really...uhhh...I'm not sure this *inaudible* design for garden maybe we can put east wing-

M: *mumbles* I think just now...I assume there is some behind garden

M &K: *laughing*

K: but we can, uh we can see the…some story in this garden so...you know this is a castle and this is fountain

M: yes

K: and like…we have a big

M: yeah *laughing*

K: and good organized garden here...so...

M: and last...then we make some tower, tower. *laughing* tower, ah no no sorry no

K: no i don't think so...we have a...a...like a umm….passage here

M: yeah

K: like this X and Y axes

M: um hm

K: so...I don't think we need to stay simple in this side so...

M: yeah yeah…so do we need these three stones?

K: ahhh, maybe no *laughing*. But, our challenge is use as many stones as possible, so *laughing*

M: yeah yeah yeah yeah, and we make this more colorful

K: *laughing*

M: yeah..eh surprise

K: yeah I think this is good...

M: surprise yes

K: maybe we can

M & K: *laughing*

OB-Y: so, can you talk a bit what is going on here because I know you have some concepts and I followed but not all...so can you talk about the different parts?

M: ah ok

K: um hm

M: first this this parts do you know? This is one main castle...

OB-Y: um hm

M: and this one maybe is a b..bi...big tree or other mmm buildings…

K: yeah like a west wing

M: yeah so so so, to serve this castle and this one a fountain, and, and the owner of this ca-castle, can see some scenery from the...the…yes the highest stairs to maybe...to look this. And first, we can see this one, this part. This part is one big decoration.

OB-Y: hmm...

M: yes. Is...hmm…is...*speaks Japanese* (searches for words)

K: ummm I think what we are thinking…important is...like color…

OB-Y: um hm

K: she wanted to make the garden colorful…so

OB-Y: yeah

K: so...we put a...many stone with different colours for example this is yellow stone

M: um hm

K: and...mmm…others…

M & K: *LOL

K: umm...what we umm...think is a balance of the height, I guess

OB-Y: hm

K: we put um...you know when we put the stones...we say like low stone or high stone so I think we think the relationship with...about height is important

OB-Y: hmmm…

M: yeah

K: umm, I don't, I don't really...have con…ahh strong concept, just make a main building, then...I divided this box into two parts, like a building part and a garden part (hand gesture), then…

OB-Y: um hm

K: for some reason I think the garden part can be very organized

OB-Y: um hm

M: and ehh...in order to...keep balance, um you can see umm...wi...first we can see this two parts

OB-Y: um hm

M: can see the same part is a main stone and…

OB-Y: um hm

M: um, the structure is also the two make circle to surround the main stone, this one is the same

OB-Y: um

M: and from this two parts you can see...ummm…the the the nearer one, is yellow one and the nar..yellow one...and the main stone is this one, it's the same color and it's also taller...

OB-Y: hm

M: and...the...and and these four structure is also surrounding...surrounding...surrounding...and surrounding...

OB-Y: um

M: and to make the same...and keep balance...the the totally balance...

OB-Y: ahhh. Did you ah, make this on purpose, like ah…the matching color and matching color?

M: ummm...to be honest at the first, I...I... put this stone…I...I never I never...discover this point...

OB-Y: um

M: but, when we, when we ummm, yes made this puzzle

OB-Y: hm

M: I discover this one...and it's “oh so nice“

OB-Y: ahh

M: so kee…keep...keep, keep...keep this

OB-Y: yeah

M: to to…yes the former from what...power position and never change it

OB-Y: ah, so kind of discovered by accident...

M: yeah yeah I think so...

OB-Y: but decided that it was good. Ah very interesting, it’s ok it happens a lot actually. I wanted to know, ah you said that this part (points)

M: um-hm...

OB-Y: is a kind of building right?...castle?

M & K: *laughing*

M: right...

OB-Y: so when did you imagine that there is the...an owner there, watching?

M: um, eh? (unsure about question)

OB-Y: like at what point, when did you start that there is somebody is here and he’s is watching?

M: ohhh, I think when the K made this fountain to this forward (wants to say direction), and I, I see oh from this position to watch this tower is so nice...

OB-Y: ahhh

M: just, just this...I, I how about you?

OB-Y: yeah I was wondering if...you have…

K: ahhh I have n...never imagined about people watching the garden from, from this position

OB-Y: um

K: so...when she explained I…from this kind of view

OB-Y: um hm

K: I was like oh!

OB-Y: you were also surprised?

M: yeah, surprised

OB-Y: me too me too, I was...also surprised. Wow, hm, very nice! I had some questions...but I think it's ok...hmmm. Oh, yeah I was just wondering, why..I I don't know, it was right in the beginning, you said, I like you want to exaggerate the height of this one, (points) -

K: um hm

OB-Y: so why did you think about that?

K: ummmmmm…I don't know but, yeah, I don't know but, I think the contrast

OB-Y: hm

M: hm

K: between high, high and low...

OB-Y: um

K: is one pattern of design

OB-Y: hm

K: you know, if you design something,

OB-Y: hm

K: you make a difference

OB-Y: hm

K: about height...so...for me that is one pattern...

OB-Y: ahhhh

K: of designing something

OB-Y: that's nice… you also mentioned I think...the differences right?

M: yeahh…then I...visit some gardens

OB-Y: hm

M: I found a point that is always high and always low, it's so boring

OB-Y: ahhhh

M: they should make more change...

OB-Y: hmm

M: to make this scenery more colorful, and the vis...visitors can...when the...at the first time...when they go to this park, if they always tall and always…"oh ok that's so-so", so and can never...never come there twice...

OB-Y: ahhh, yeah just understand (it) the first time and then...

M: yes…I think...I think this…

OB-Y: what kind of gardens are you thinking about?

M: ummm...because I'm Chinese I always with the Chinese sty…style and...

OB-Y: hm

M: and in Japan...like the Fujiyama, Fujiyama have many *inaudible* with the Japanese traditional gardens….

OB-Y: yeah

M: so I really like it

OB-Y: ohhh, wow

K: for...for the first garden I imagined the Ryōan-ji

OB-Y: oh

K: yeah Ryōan-ji so…

um hm

K: when she mentioned, eh oh you can, from this side we cannot see this stones...

OB-Y: hm

K: so...I think we...shared the image of that temple...right?

M: yeah…*laughing*

OB-Y: ahhh

K: but for this part

OB-Y: hm

K: because...since the last one was about Japanese gardens, so this is more western style so it more like a...many stuff...you know...

OB-Y: hmmm, wow. Ok final question...like…just think for a second, don't say, like if you can give this one a title, but separately.

M: umm...ok ok

OB-Y: and after you have a title, say what you think...I don't want you to...yeah...

M: ok I will think myself...

OB-Y: ahh *laughing*...*long silence*. You have it?

K: yeah...

OB-Y: Ok?

K: umm, my title for this garden is just like "average western style garden" like

OB-Y: *giggling* ok...

K: because…

OB-Y: *laughing*

K: I have a reason…because because the…first one-

OB-Y: um

K: I focused on designing the garden

OB-Y: um

K: like a...I was think about how to make a...good garden

OB-Y: um

K: like how to design the…blank space…

OB-Y: ahhhh

K: but for second garden...I just...umm, focus on make a difference from the first one

OB-Y: hm

K: so my focus was making western style garden

M: hm

K: not like a...designing a good…

OB-Y: ahhh

K: ahh space...so...this is...for me, this is a…average western style garden...

OB-Y: ok, nice

M: and my...my title is like some article's title...

OB-Y: yeah

M: "stay...stay higher..."

OB-Y: yeah

M: "scenery is more beautiful this way

OB-Y: ahhh

M: cause...if we stay in the low...just like this point, we always, we can just see some boring scenery, um, comparing (wants the say relatively) boring scenery

OB-Y: um um

M: but if we stay the higher, the higher scenery, we can see; "ohh this one is beautiful and this one is different! Oh it's colorful!" this way…

OB-Y: ahhh

M: so stay higher - see more colorful this way...

OB-Y: hmm...very nice!

A.4.6
{1st composition}

N: so the tools is our hand there's no other tool

OB-Y: yeah

N: ok ok

OB-Y: by the way, I can give you this one, if you want to use it (handing small rake), but we will only analyze the design of the rocks. If you want to enrich the design with this its ok..

N: ah so, like you are saying like you only design…like you will only analyze the design of the rock, so then like the surface of the sand itself – you will not consider it as a design

OB-Y: I will think about it as less important, it is important but less

N: ok

D: because…I was thinking now of…burying rocks, but I don't know this…sand allows for…ah it might…

OB-Y: you can try!

N: yeah you can…you can make…

D: …a small one (hole), maybe…complicated, I don't know about that

N: but the intention for burying the rock what is that? to make like a small…

D: I was just thinking just how good it look…if it's just eh…mounds instead of rocks. Maybe you don't see the rock…

N: *laughing* but maybe you are killing the exercise…

D: does it work? I am destroying your…I don't know if this eh…

N: that is totally unexpected…for me. for me I was not expecting that eh!

OB-Y: me neither

D: we can, we can…we can change, let's eh…this was eh-

OB-Y: unexpected!

N: but for example, like for me, I think that what Diego is doing right now, like this action of…as we have only like two elements…like the sand and the rock, like the interaction between these two is key for the design

OB-Y: yes, I think so too

N: so for example like…not only like the placement of this, of course we should consider, because I guess like in the rock design (it) is very important! but how this…so maybe is not completely buried, but maybe…

D: yes um…

N: …maybe is

D: showing a little bit…

N: I don't know if…a strategy…strategically we should like kind of first like make the…prepare the terrain for the rock, and then place it

D: place it…

N: so…it's not totally, it's not totally…it's not on the surface like this (placing a rock on the sand as an example) right?

D: but just um…

N: but you are somehow like making an interaction with the…well I don't like a role of that....

D: it like the *inaudible*

N: no, it's not the *inaudible* that like, for example like the sand here is um…

D: is messy

N: is totally messy

D: and I think we can…after that we can, try to make it eh…I don't know

N: ok. And about like the use of the size of the rocks, because we have different size here, so there's like very tiny ones like this one

D: yes

N: medium size and like…the very…big one

D: ehhh…I like the...doing hmmm…several…

D & N: trials (in unison)

D: yes

N: yeah I think so

D: so If you want we can try one…hmmm…

N: yeah

D: hmmm…more…I don't know…

N: yes

D: freely…or come up with a strategy, if you prefer

N: yeah, yeah

D: we can say, ok let's concentrate…one, in one corner

N: for example…

D: and try to…kind of concentration in one corner and try to dissolve towards the…

N: ah that can be. But…

D: but then another…

N: but as we already have this one…

D: yes

N: I would use this one to make the first trial…ummm, maybe the concept for this design…is the…somehow like the interaction between sand and rock. So we can make like different…with different rocks

D: different eh…

N: we can…different…eh…rock and...

D: design…like different interaction between sand and rock, ok

N: exactly. So in this one, like the most important part is not going to be the placement, but the…how is it placed in the sand

D: ok, ok

N: so

D: this one is

N: (interjection) so we have two types (of rocks already placed with some relation to the sand, pointing at tray)

D: like eh…placed and…kind of

N: Maybe another one…can be…

D: one can, has to be buried, I think

N: totally buried…and another one has to be… just standing

D: this one which is flat, I'm gonna bury somewhere…(looking for place while moving hand above different position)

N: ok, and I'm…

D: here

N: where?

D: no we can also make a gradation of of…exposed and buried

N: ok

D: somehow, I don't know for *inaudible*

N: but maybe this is, this is whatever placed here (pointing at rock in back right corner)

D: we can do it on that diagonal. Like for example, this one I buried, then second one, a little bit, the third one almost, and the last one like very exposed

N: ok, ok ok ok, I like it (agreeing willingly).

D: so this one we can…(puts rock aside)

N: Ok so…about the size, we don't care?

D: because of the…

N:…of the rocks for these eh…we don't care no?

D: maybe…similar, or…

N: similar size?

D: do you think, or…?

N: for example like, this can be like…or is (it) too big. This can be the last one? (considering to add another rock at the end of the series, at the back right corner). Or it's more…I'm in a

D: maybe it can stand out?

N: like this one?

D: yes, perfect

N: (smiling and laughing)

D: then half, I'm doing half-in-half-out

N: Ok, and I'm doing here…(pointing to a desired position on the tray)

D: which one is nice? (wondering to himself). This one I like, it looks like an arrow

N: I want to place another one here (decisively, pointing to a place around the previously pointed one)

D: ok (quietly, seems to be concentrating on something else)

N: 'cause this is the diagonal no?

D: yes. kind of a (gesturing with hand in the direction of the diagonal).

N: so I'm going to prepare (digging a small hole in sand as preparation for next rock)…this one was completely buried but…so this gradation here is…is going, like the intermediate ones…are going to be…

D: do you want any tools?

N: not so exact, as for example as being totally standing out

D: need tools?

N: nah, I'm fine with the fingers….(laughing). This is not so round (holding rock)

D: you want round? This one (the one N is holding) is nice I don't know,

N: I don't know

D: like this one (picks up a rock)

N: But I'm picking round just intuitively, as…actually this is not really round (points to back right corner rock) like what I mean like the corners, this is more…edgy

D: ah so you just want like kind of…but then maybe

N: this is like round…

D: …another transition of form, kind of, maybe they (will transition) from more *inaudible* to more pointy…

N: but this (back right corner rock) is more pointy than this one

D: but we can change it, even though that one (back right corner rock) is nice

N: nah. I really like this because I like…(hand gesture of an upward movement) this emerging

D: you like the pointiness, ok.

N: yes.

D: two more, no? one here one here (points to the prepared dimples in the sand)

N: yes

D: ok. This one is…(refers to second rock from the left)

N: ok

D: somehow…this burying not-burying

N: (wonders to herself while holding rock) how about this…ok, I will use it in-

D: that one is nice

N: (picks up another candidate and seem as about to change her mind) or this one, this is (the newly picked one) is too big no? (places the newly picked up one back) ok this one. In which direction?

D: I don't know, you just eh…

N: because maybe…

D: you need one that is half-half no? This one is, kind of starting to emerge…

N: but actually, now I'm realizing, like the…the size of the, for this exercise of the emerging rock (laughing)…

D: this? (points to middle missing one)

N: the size of the rock is very important

D: so most of the time it's similar no?

N: yeah because, it's not create…yeah

D: this one is surfaced with the…

N: ok

D: no? the other way?

N: no no, it's it's totally fine. But, what to do with this one (points to third rock from right)? because actually this one seems more emerging than this one, because of the size

D: but we can cover a part

N: ok let's cover

D: you want to use the…? (handing over rake)

N: so actually like, I'm relating…like the actual size of the rock is not so important, but the ground is creating kind of a fiction, of the real size, so it's like an iceberg. No? (speaks Spanish)

D: yes, iceberg.

N: (laughing)

OB-Y: yeah it's hiding behind the surface?

N: yes yes yes yes

OB-Y: (laughing)

N: are we talking a lot?

OB-Y: that's completely fine! (laughing)

D: or not enough…

N: or not enough, I don't know (laughing)

OB-Y: (laughing)

D: we usually…

OB-Y: if I don't say anything assume, you're fine

N: no no, if you want to say something please, or collaborate in the design…

D: it's very, it's very (happy about the activity)

OB-Y: thank you

D: yes if you have a, any input….

N: yes yes like…review already

D: client…it's…I'm not sure…

N: yeah you are our client actually

OB-Y: (laughing) kind of client…

D: shall we do the, lines with this? (referring to the rake)

N: yes

D: it's because I'm not –

N: actually I'm trying to (use the rake)…but I am not so good at making models so

OB-Y: it's not so easy as it looks, like…

N: no I don't know how you manage to…fix the sand, and make it perfect

OB-Y: yeah everybody finds out that it's difficult. I use that one, the black one, the ruler…

N: whaaa, so difficult

OB-Y: without it, like with the small tools I find it really difficult

N: wow…

D: (mumbles)

N: ah its very nice, I like it, because you're creating somehow a path, of the emerging rocks (refers to the manner in which D manipulates the sand) (laughing)

OB-Y: hmmm (laughing)

D: we say that, oops…(speaks Japanese: gomenasai, translation: sorry). Should we, or…try to do be more…? (gestures a circular movement with hand)

N: are you satisfied with this emerging one? (points to third rocks from right)

D: which one?

N: the one that I did…(laughing)

D: yes (stressing satisfaction)

OB-Y: if you talk about some one, like some rock, point to…

N: this one (points to third rock from right)

D: yes, huh?

N: do you think that this is like eh…the gradation between this one and this one is ok?

D: yes. I think its fine. Because this one already has like a…hmmm, you know it's already separated from the ground

N: yeah

D: and the other one is still the…the sand is…

N: ok

D: should we stop or…? because the surface is not so important, I don't know…

N: no but if you're doing that, you have to finish it.

OB-Y: right.

D: ok so the next one, let's talk about the next one…should we do the…

N: ok, this one is going to be like the first one no?

D: yes, should we do gradation of-

N: how long?

D: of density?

OB-Y: uhhh, I didn't measure but for now its ok.

N: (laughing) ok but, because if we are too fast or something, because when we work we usually make a lot of trials, actually.

OB-Y: really?

N: yes.

OB-Y: oh that's perfect, so you can work in the same style

N: yes yes…

D: ok, (speaks Japanese: daijoubo?, translation: is it ok?)

N: I don't know if we are committing eh….some kind of, bad offense with the buried one (points to tray, seems to enjoy "bending the rules")

OB-Y: (laughing)

N: burying the rock (laughing)

D: yeah. No because no…traditional burying places, no the Japanese ones are also mounding

N: I hope!

OB-Y: right

D: but I have…I think life and death (points to the two edges of the composition)

N: ah yes, emerging

D: should we…we can destroy?

OB-Y: yes

D: destroy…

OB-Y: (laughing)

D: what do you like for the next one?

N: ehhh, you were saying before….something that I like, to make a gradation of the accumulation of rocks. So, from one corner, then to disperse

D: (completes N) dissolve. Ok

N: no? I understood that. Is that ok?

D: (mumbles in agreement)

N: do you have a….

OB-Y: tissue?

N: yes please

OB-Y: oh I'll get from the other one

N: sorry

OB-Y: no, its ok

N: this works (refers to the black ruler and the way it smooths out the sand). I have an allergy I think…

{2nd composition, 12:01}

D: ok, no?

N: yes

D: or this...(mumbles)...also

N: this works, yeah yeah yeah the ruler

OB-Y: yeah yeah it's much easier with this one

D: but i'm not eh...doing it...well...

N: ok so now, yes, maybe, maybe the accumulation here (points to front right corner)

D: I don't know

N: ah it's fine, I guess…ok, no?

D: enough *inaudible*, later we can

N: yes

D: fix

N: ok for this accumulation, I think that we should consider the size now

D: yes

N: ummm, for example prepare the rocks before, like the bigger on the side so…we can…ehhh…(saying this while moving the available rocks around as if sorting them)

D: ok. Should we start putting or?

N: yeah you can…you can start putting

D: ok

N: so, to the smaller ones…

D: they, they can touch…can they touch? (asking about the rules of the exercise)

OB-Y: yes, no problem

D: ok. just…I'm just, placing, kind of creating a core… density, so maybe, if you want to also…

N: ok

D: maybe the ones that look nice, the smaller ones, the ones that you like

N: these ones no?

D: yes

N: I'm preparing like the small ones for the end. This are somehow medium size, here…and I think that there's like these three categories

D: there's also color, ah but color is not…an issue no? color of the rock is a…(again asking about the rules of the exercise)

OB-Y: could be an issue…

D: ah could be (a bit surprised), ah maybe…

OB-Y: yeah that's another thing

N: but maybe this is another…concept

D: for another…

OB-Y: (laughing)

N: so, yeah I guess that actually, for us it's important to…put like kind of a main topic, and then like other things, maybe are accompanying this main topic but somehow…not so important. So for example, if the previous one was the "emerging" one, here maybe the most important thing is the density…

D: yes, you just can…density and (showing a movement of spreading with hands)….no?

N: and dispe-(wants to say dispersion) yeah like the contrast between…

D: and like the…

N: so maybe here we can start dissolving (gestures with hand from the far left corner of the tray toward the close right one). We are making another diagonal in the other…ehhh

D: do you want not a, not diagonal?

N: no, I don't want it

D: you don't want diagonal

N: I want to…I don't know why (laughing), by I…for this time

D: yes

N: to make it a little bit more diverse with the previous one…

D: yes

N: I would actually like…maybe it's because of this line that was randomly created here (refers to line in the sand created while raking in the beginning to clean the tray; laughing), but I want to create a…a void here (points to right side of tray), and then make this dispersion - it's not exactly this line ok? –

D: ah so…

N: but like kind of like…

D: ah so, a lot of void… and…

N: more void like…

D: from this line void (hand gesture delineating the line and moving right)

N: more or less

D: ok

N: so we can make like the dispersion here…(hand gesture from left of tray to right) and then here a void (hand gesture to right of tray)

D: ok. I'm going to…but then I'm going to compress (the group of rocks)

N: yes, you can compress…and then…

D: (speaks to himself) these guys…

OB-Y: definitely speaking enough…(laughing)

N: (laughing)

OB-Y: good good good (laughing)

N: yeah maybe…we speak a lot

D: this is close to what we kind of do…

OB-Y: really?

D: yes because…yeah I don't know if it's our Spanish genes…

OB-Y: ohhhh

D: that…kind of…we cannot stop talking

N: yeah when you were saying 'you should say everything'…it was like ok that sound very much like me…

OB-Y: (laughing)

D: we think…

OB-Y: maybe I should only ask Spanish people to join (laughing)

D: no no but its…

N: no because as you are seeing we are really transgressing the rules of the Japanese garden, so right now I think that we are making like a rocky…landscape (laughing), rather then…

D: should we start to dissolve…? or when do you…

N: yes right now I think we can start dissolving

D: ok

N: so I like this, this distance more or less no…?

D: yeah…it's like that it feels a bit…ehh…no? kind of…

N: so I would like, kind of like start separating them…

D: ok

N: with more or less like this distance…

D: I don't know where to place this one…

N: hmm, placing this one…

D: I guess were also doing a little bit of diagonal…no?

N: yeah but I would rather like try to…(gesture of half circle with hand)

D: like a circle, kind of

N: like for example, occupying with the dispersion, but until…until more or less here (points to an imaginary horizontal line which is a bit after the front of the tray), I think.

D: ah maybe I can, sometimes it's also… no but…to create…(mumbles) things…but maybe (speaks Japanese: "daijoubu", translation: never mind).

OB-Y: what are you thinking D?

D: no no I was thinking that maybe, we have one big group here, and then it starts to dissolve, I don't know if it's also interesting to add another group, in another point…(means location)

N: yeah, I think that...

D: maybe...here or or or where do you, do you think…

N: ah, because you are thinking in three different groups (tries to understand how D sees the situations)

D: no, I like the dispersion, the density and dispersion…

N: yes

D: but I don't know if maybe there is another focus of…density here (points to near left corner of tray), so it feels more like the dispersion towards that side…

N: so in that se-…in that sense you want to create like also the density here, but the only problem is that we don't have enough rocks…already

D: ok so then…

N: so maybe we can…

D: then its fine. let's do a…

N: we can…

D: same exercise…

N: place them here…

D: (speaks Spanish), here. All of them…should we use all of them? yes, no? we have three

OB-Y: you don't have to, but…yeah

D: we have three left, or not…what, what do you want? I feel bad for these three…

N: you can create the density that you want here…no?

D: yes, maybe (speaks Japanese: daijoubu, translation: no problem). Can I put one…? we can move right? no? it's not like its set on its, like once its placed, we can move right?

OB-Y: totally

D: so, how do you feel? N? (speaking to oneself) here? yeah, last one…all the pressure for the last one (last rock), here (hold above front right corner which is the "void" area) no…(places on table as if gives up or allows N to place it)

N: really?

D: no no…

N: no…but

D: I like the… (supposedly means the void area). It can be…closer to eh (points to the middle dividing line in the sand), or do you like the…(hand gesture of division between two sides) line?

N: I don't know why I am affected by this line that was very randomly created...

D: yeah…from your side it's different…

N: yes! like the thing is…from my side is different maybe…

OB-Y: you can…definitely change places if you want..

N: yeah let's change

D: just to see

N: oh but from your side it's also nice…

D: oops sorry (hit the camera device)

N: I don't know why I'm going for the…void um…

D: I think eh…I like this one, so we can place the last one and…ehhhh, change to the next one, ok

N: yeah

D: ok, (speaks Japanese: daijoubu: translation: ok)

OB-Y: hm, before we move to the next one

D: ah yes

OB-Y: before we move to the next one, can you talk a bit about this one?

D: do you want to… (proposing to N to speak)

OB-Y: anything it could be criticism if you want, or eh what you like about it, or what you tried to make…

N: actually, I think that really depends of the experience of the garden itself, because I think that the…the contrast between these two sides, when, for example if you're like in the scale of a person…for example let's imagine a person like this (shows a size of a tiny person with hand gesture), right? for example no?

D: like as tall as this rock…(points to tallest rock, the one in the back left corner) no?

N: yes, and remind like…very big rocks, so like the experiencing of walking here, can be like very…and then you can hide for example, or lie between rocks. But of course it's not the way to use a Japanese garden, so sorry about that. But I also like, like the feeling of…eh, having the contrast between like very empty space, and a very crowded one (refers to the two different areas of the composition with a hand gesture, i.e. right and left), kind of like the rocks as entities, or as…even like…

D: or as people…no? there's like a…

N: as living things…living like…

D: they kind of gather and then…

OB-Y: ohhhh

N: because like…in this kind of like, gathering position

OB-Y: um hm

N: they look like, uhhh, like a group, with all the agency that has, like so…

D: yeah they look that…thinking something…

N: they look like they know…(laughing)

D: they're thinking something bad, they are going to…(humorously)

OB-Y: (laughing)

N: not!

D: there's some kind of…

N: because like the logic in the…in this kind of like eh, accumulation, there's like a point here (points to top of tallest rock, in back left corner), a force point, invisible, but somehow its attracting the rocks towards this final one, like the vertical one

D: it looks totally like a leader of ummm…rocks, somehow, that corner

N: so I feel like probably like the….

D: maybe…(mumbles)…yeah

N: but of course we are making all this up because we have to say something…

D: yeah but that's, it's also is clear as this, as the first one, it's clear to express things kind of…contrast no? like eh…maybe we also…that's maybe not very Japanese, but we think very much in kind of concepts, like eh, ah ok we have this, and then we try to achieve that somehow

OB-Y: yeah

D: and, for us its very…I mean we can experiment on the way, but we…ok we have this idea of, so If you put this kind idea of concentration or density, then it's easier to see voids, it's easier to think all the things, because there one kind of core idea

OB-Y: yeah

D: one form or one ehhh…concept, then other ideas can unfold from that big ehhh, kind of, not gesture, but maybe totally opposite from what it should be, no like? maybe it's more ambiguous and…not…because if you show this to someone maybe it's very easy to say, ah! density, or black and white! or….

OB-Y: uhhhh

D: but maybe Japanese garden is more about eh…ooh, I don't know why this rock is here, so more less…more…no? I don't know

N: yes

D: maybe we are doing it in a way driven…

N: (laughing)

D: maybe we can say for the last one doing it…ah no but we have to talk…but then without a concept, no?

N: without a conept…

OB-Y: ahhh without the concept. That also would be interesting, but I have to say that what you have done so far is completely fine, I mean in term of comparing with the Japanese style, because we are not really interested in the product, more about the process

D: oh good

N: ok

OB-Y: yeah, so even if you have your own way to work, and…everything is done in your own style, that's really really fine

D: ok

N: ok

OB-Y: yeah, wooow, so this one is…finished (confirming with the subject)

N & D: yes yes

OB-Y: ok. Usually I just a small still in the middle, because ummm,

D: ah so we should have told you…ummm, in the middle?

N: he took…

OB-Y: ah no no, like when you finish, I mean like when you finish one composition, I take a still just in case, because the image from the phone camera is so-so, but if you want an image of the finished one, it's good to have that.

N: ok don't worry

D: we can…

N: yes yes. Ok

D: we can also do like…ok from this one…final….

N: noooo

D: ooh but I like the…the…(holes that remain in the sand after removing rocks)

N: (enthusiastically) ooh yes, leave it leave it leave it

D: can we…not…you mean the…

N: like the…footprint of the…

D: yes, of the rock. But that, that doesn't count for the…no?

N: no but we can use it, for the next

D: no I like this, but, but what I mean is…for you, for your study, doesn't count so much the treatment of the sand, no? like for example…

OB-Y: ahhhh

D: what?

OB-Y: not so much…

D: like the...emptiness of…like we were liking 'ah there is a rock there but there is not the rock anymore'

N: we are really appreciating the void that is left, like the…

OB-Y: ahhhh

N: the…

D: footstep, no? the print…yes

N: of the rock….

OB-Y: I think that count as well

D: counts as well? ah, oh nice

N: but I also like these kind of….ehhh, discovery during the process, that...this is totally unexpected, so we were not like planning to...appreciate the, the footprint of like the...but by working with the sktech or hands or model or in the project itself, sometimes during the process some things are revealed that were not there before, that can be like kind of like the...thread for another line....

OB-Y: right

N: of thought I guess

OB-Y: right

N: so I don't know if you want to use this…

D: and you're interested in people working together no? At the same time

OB-Y: ah so we do like usually either one person, or two people

D: ah ok ok

OB-Y: yeah. And it's very different by the way

N: really?

OB-Y: yeah, one person tends to not change so much, unless they are professionals, you know they go one way, and in a couple there is always this kind of balance, somebody want to do something, somebody want to do something, and then they find a way to…

N: negotiate

OB-Y: work together, yeah

N: yeah yeah

OB-Y: but one person, if he is not professional, usually goes one way, like idea-solution-finished

N: wow

OB-Y: yeah its very different

D: (laughing)

OB-Y: yeah, so like a couple makes it way more interesting, and way more complex

N: really?

D: yeah it's interesting, yeah that's, actually that's h-

N: I really want to read the paper

D: that's how we, that's how we, that's how we work

OB-Y: yeah you experience this in real life

D: yes, because actually we always want to have a third person, like eh, in our mind 'ah we would love a third one, because a with third one there's ma-'

N: you (referring to Y), that's why we're inviting you (laughing)

D: there's majority, and then...sometimes when you're super stuck, the third one is like 'ok, you both guys see that this one is the one, ok I kind of trust both of you, we go..', but if both of you are kind of, you know posit parts, there you are forced to convince the other person.

OB-Y: somehow…

D: which is..it's good

OB-Y: yeah

D: and also, but more...takes more work, always fighting and then…

N: and always

D: trying to convince and negotiate

OB-Y: yeah yeah yeah

D: and sometimes it's like 'I like this one, but you don't like it', then we erase this option, and then start from the...start from the scratch, until we...kind of meet somewhere

OB-Y: ohhh (laughing)

D: so I th-, I don't dislike it, I think like working two, and also all the time back and forth, until it's…

OB-Y: yeah

D: probably more interesting for this…

N: yeah but eh, the, the third entity is more interesting, because right now we are being very well-behaved, and we are polite, and we don't...scream and bla bla bla

OB-Y: (laughing)

N: but, but for example, when there's like very...two strong ideas…

OB-Y: yeah

N: like, I have (a) very clear option, and he has (a) very clear option

OB-Y: yeah

N: but this third party, if he or she doesn't exist, it's very very difficult to take like the...the decision. And it doesn't seem democratic at all, because when you have your standard very clear...

OB-Y: yeah

N: then there's like, really one, very clear that one winner and one loser of the final eh…

OB-Y: right!

D: no but it think, but I think it's, it's, it's a good thing because in the end-

N: really?

D: you're, yeah (response to N's doubt), because in the end you have to convince….

N: clients, yeah

D: eh, I mean of course you have to be open to receive the...input

OB-Y & N: yeah

D: but eh, if you want your option, and... really you think it's better than the other one, then you have to come (up)...with arguments

OB-Y: right

D: to say...

N: yes

D: then that's for us...

N: yes yes yes yes

D: I think is…

OB-Y: you have to be like, brave to stand behind your idea…

D: yes, but if, if there's three, it's like 'ok no, both of you, ok now we can erase, even though this idea might be better, no? But th-

OB-Y: ahhh

D: just because two people say that it's not…

N: ahhh

D: then, it would be decided to...I don't know i'm just convincing myself that it's good to be…

OB-Y: (laughing)

D: working with you (with N) and screaming

Y&N: (laughing hard)

D: every day, for everything like 'nooo this, no this!'

OB-Y: how long have you been working together?

N: eh, since school, so we've met in the...in Madrid-

OB-Y: uh huh

N: architectural school, so maybe from 2011…

D: I think the first time that we've worked kind of together was 2010

N: when we were eh, still undergraduates

D: and then working full time together (laughing) but full time is, 24 hour, 7 day, 365…

OB-Y: two jobs (laughing)...

D:in everything, since eh I don't know, 2012 I think, when we started the final thesis project, and then, we did it kind of together

OB-Y: wow!

D: first one...then the other ones, so...it was…

N: yes yes yes

OB-Y: so you're used to…(laughing)

D: yes yes, it's, it's...I think…

N: yes, yes yes

D: we like it…

N: I don’t know if we are good at, I think-

D: I don’t know

N: I don't think that we are good at rock gardens but…

D: but it's fine

OB-Y: it’s ok, think about it as “F studio garden” (F is the name of their studio”)

N: (laughing)

D: ah exactly, exactly. Ok, what should we, what should we do for the next one? Do you want to go, process ehhh, like not think of an outcome

N: let’s try to challenge the process, because as they are...because right now we are being like, as we work usually, no? We throw things, and test them. But maybe right now we can think about changing the process?

D: one thing I was thinking maybe you can start, or I can start, I don’t know if it works with you (referring to the rules of the task), and work for two minutes, and talk while you're doing it, I’m here but I’m not, eh mmm, saying anything, and then after that I come and kind of mess with your thing, and then if you want to...do three rounds, or something like that

N: really?

D: I don't know, it's an option of messing with the process, I don't know if eh…

N: ok

OB-Y: as long as you explain what you did after, its ok

N: ok

D: yes, I think...or what do you think, do you prefer another way of challenging the process, what do you think?

{3rd Composition, 30:56}

OB-Y: if you want to have some challenge, maybe you can create one composition, you can create another, at the same time, and then, at some point you can try to…merge. Like, ah, you can work on the right side of the…

D: ah ok

N: ok that's a good idea!

OB-Y:…then try to integrate somehow

D: ok

N: ok that's a good idea

OB-Y: would not, not be so easy

D: it's good. it's maybe like a chess…a chess match, no? I put here and it's…action-reaction. Maybe that's good, that's a good idea.

N: ok

D: do you think…?

N: yes yes yes yes yes

OB-Y: ok

D: (laughing)

N: oh it's very difficult because they accumulate (the sand)

OB-Y: yeah yeah yeah, (laughing) it's very gentle.

D: yes yes

OB-Y: not like the real ones you use, like a rake or something (laughing)

D: that would be…I mean of course it's makes more sense, but I would love to do it in a full-scale

OB-Y: full-scale – me too!

D: but maybe, moving one of these eh, it's impossible

OB-Y: yeah, we can go like, one scale up maybe next time you know, one table or something…

D: yeah like eh…

D: yeah would be nice to…

N: ok

D: because also, if we experience, like…you know this... to experience the space or such, maybe it can be done with a room, with…not rocks but maybe I don't know chairs

OB-Y: it could definitely happen yeah

D: or…furnitures…

OB-Y: hollow rocks maybe…or…

D: yeah also

OB-Y: we can think about it

D: like and, because also…I don't know for us, would be also like…no?

OB-Y: to walk around…

D: yeah to walk and see and, uh, maybe, you know like

OB-Y: yeah, I think in the small scale some, some of the real dimension is obviously lost, you know, of experiencing the thing, we look at it like an object

D: yes

N: yes

D: ah but also, also, it's it's…I mean it's like a model, no? we're used to that…

OB-Y: definitely, we can imagine, so…

D: but eh…yes, because we cannot experience buildings, at the same time, but this maybe there is a way of experiencing it (excited about this idea)

OB-Y: maybe there is! it's very inspiring you know…

D: ok, eh, I start.

N: but we should it simulti-, simultaneously (asking about the rules of this session)?

OB-Y: yes

D: yes yes, I like the…and we have to talk, but eh

N: and we talk…but

OB-Y: I mean like, I'm doing bla blab la…

D: do you want to eh…take turns, or the same time without…saying anything

N: ummm, I'm already…

D: wait, I'm putting one here (decisively, decides to act)

N: (laughing) I'm considering now like the colors

D: ah colors, f* it but eh…then it's not going to be…separate eh..

N: yes it's separate, you're just putting one, I'm considering

D: ok

N: (laughing) no, I'm considering, I'm picking right now, like the one that are like, very, that have like these…

D: textures

N: like hybrid texture

D: um, that one is nice

N: so, I think I'm only going to select these ones

D: ah only the…

N: for me, for me right now, this matters a lot

D: so maybe like…like a family

N: yeah a family of rocks with these textures

D: um hmmm

N: so I don't want at all like the rest

D: ah give me the …

N: so for me, right now my idea is this, so…actually maybe only have these two

D: only two? wow

N: yes

D: you have all of them

N: really?

D: *inaudible*

N: no because I don't see the…I don't see like more like this one right

D: but you can find similar in other colors, make families, or not? what do you…

N: ooh, we are already collaborating! (laughing)

OB-Y: oh you see!

N: yes!

OB-Y: that happened naturally

D: sorry, but eh…(speaks Japanese: Daijoubu, translation: no problem)

N: yes I'm, ah families is very nice. And we have like this obsession for classifying all the time, you see? like…

OB-Y: yeah

D: yes, maybe it's not eh…

N: I, I'm…

OB-Y: having some categories..

N: and then like, had the biggest one, the tallest one like the…

D: because also the…we're used to work with context, no? of things, of clients, money and…where's the sun, what is this for…and then, so for this we have to make up our own, no? rules

OB-Y: right

D: even though, maybe it's not needed

OB-Y: right, yeah sometimes it's needed

D: but eh, it's like "ah ok, face, face the borders, and then we can play within the borders, even though…are completely made up

N: ahhhh

OB-Y: right

N: so, what about if for example with this family that we already have here classified, let's start to make like…for example, these two are clearly a family

D: and if we do like a super grid, superimpose grid

N: superimpose grid?

D: like a…like if its suddenly this becomes a…like a…biology, like with the insects, you know when they catalog…

N: I was thinking more for example, because as we are-

D: for me eh-, ah did you..

N: now, two concepts

D: ah two concepts, ok

N: we are already one I think

N: (reconsiders what was said) no, it's not. we are already one, I think. But for example like, I was trying to make…to put like these groups that are already classified here…

D: um hm

N: as…eh, making different tensions between the,

D: ok so-

N: so for example, these one (points to back left corner), they relate like this (adjusts the two rocks there), here right? so in another place here in the garden…I don't know which family is this one actually (looks and point and the single rock at front right corner), maybe this one (points to dark rock group in collection)

D: I don't know, I'm, I'm gonna…

N: no, this one?

D: I'm thinking the…the outcast, no? the ones that are not family…no?

N: these are some…these are (a) family (pulling back several rock which make a family in her opinion)

D: so I'm taking these five, no? or…

N: yes, and this is family also…(covers darks group of rocks with hand to stress their grouping). And this, this is another family, and this is another family

D: so, since this is family, I was thinking maybe doing it in a…very classified…no

N: I don't like it

D: you don't like classified, ok. I'm going, but I don't know what to do with these ones, ok I'm gonna try, things…

OB-Y: just taking a picture of the families

D: a sorry

OB-Y: no it's completely fine, ok

N: laughing

D: I like this (the miniature rake), because it looks like: I'm a giant!'

OB-Y & N: (laughing)

D: it's like 'oh no! what happened? now I can…'

OB-Y & N: (laughing)

N: you are su…for example like-

OB-Y: it's like the espresso cup

D: yes, like this

N: ahhhh (discovery)

D: 'I woke up and suddenly-'

N: what about like if we, like this composition is about, couples (laughing) so…eh, it's like

D: ok

N: ok these are family, he already has a family, but we put like, like the minimum unit of family that we have right now, its two right

D: couples, ok

N: so, we have another two here

D: ok

N: and we put like maybe…

D: ok, I like

N: another two rocks

D: but this one might not have a…I can, can I remove?

OB-Y: yes

D: yes, I am removing this one,

N: ok

D: because doesn't have a…couple, but maybe this is a little bit eh, problema-, ah I don't know why just putting together the one the I….

N: ah I, no no no…

D: that resemble…ok they are rocks not people, it's um (speaks Japanese: daijoubu, translation: it's ok)

N: I don't know they are in the same place…

D: yeah…*inaudible*, but they are not relating with each other, it's just only family

N: they relate in the space

D: ok

N: ok

D: it's very…completely

N: ok, I cannot make this fine…

D: hm…if not we can do, uh…I think it's fine, I will…put something…

N: ok, these two

D: on top. Ah, you're occupying my corner…

N: I'm sorry, I'm so invasive…um, can I put it here

D: of course, of course…

N: like this (refers to placement of the rocks D is holding, jokingly)

D: you want like this?

N: (laughing) no, no no. No no no. Another…let's try with another…for example these are similar no? it's same family but-

D: I like these two because (they) are kind of concrete

N: place it, ok

D: like…fake rocks. But then, I don't know where…hm

N: are we creating a space here, or are we like occupying the whole…? uh, ok

D: also…(mumbles to oneself) three is nice no? (referring to the desired number of groups in the final composition) but maybe…

N: three is nice…

D: because-

N: three or five-

D: yeah, has to be

N: I don't know why…(laughing)

D: no but…what I gotta say is like, these two couples kind of talk together (points to couple on the front right) and that one (the couple on the back left)…is kind…so…. but (speaks Japanese: daijoubu, translation: never mind). Maybe we can keep, eh…adding couples, yes I like couples, more couples.

N: about couple…

D: it's like a dance of, of…mmm rocks

N: yes! so, for example, this one here (placing a couple in the back right), and these ones…do you like these two (holding a couple)?

D: the-, these one, ah those two are nice. I like this one standing up, do you think or maybe..

N: you already put it standing up before (slight criticism)

D: maybe too, too phallic…

N: no, but its fine, no no (laughing)

D: ok, we can

N: it's fine it's fine (laughing)

D: we can put it ehhh…

N: no no, but where do you think?

D: I don't know. Let's…

N: it's true that right now…

D: let's throw it…

N: I like it…

D: do you like right now?

N: I like the…again the

N & D: diagonal (in unison lead by N)

D: eh, no. We are repeating ourselves (with slight tone of defeat) yeah…

N: why…ehhh

D: the dance of rocks…

N: ok put is

OB-Y: which is not bad…

D: um?

OB-Y: it's not bad to repeat yourself

D: ah it's not bad?

OB-Y: no

D: if, we can leave it like this if you want…

OB-Y: does it happen in real life?

N: I think a lot…

D: yes, but…eh…

OB-Y: to you guys I mean

N: yes, yeah you can like-

D: yes

N: you can trace the projec-, you can see like the genealogy of the projects, how,

OB-Y: yeah, yeah yeah

D: yeah, not…

N: how that some element…or some prototypes are totally repeated…or reused

D: yeah, also when you fix one, ok, well you start to take out branch, so in the beginning it's like whatever flows

OB-Y: yeah

D: and then you start to cut…branches, and then you have three, and then you have two, and then you have just one, and out of that one – five, no?

OB-Y: yeah

D: so, then you start to 'ok, we have the diagonal theme', but then you start to…play with that one

OB-Y: ahhh

D: and then other five, but with an…no? it's just, always I think

OB-Y: so it still exists as an option, maybe you won't use it, but

D: yes

OB-Y: it comes up as a "branch"

D: yes, so I think yeah, it's always making options, no? oh what happened N?

N: I put one

D: ok, yes

N: unintentionally, but actually I don't know if it is good

D: ah it's good it's good

N: because right now it's parallel to this one (refers to the other close light gray diagonally placed rock), from my perspective

D: ah but then you can put this one, make a couple but put it maybe...far away

N: but if you put it too far away, then it stops the tension between them

D: looses the…

N: of the couple… you have to keep it, no?

D: no (is not satisfied with the way he positioned the elements), they are similar to another one

N: maybe we, I can remove it

D: no no, it's (speaks Japanese: daijoubu, translation: no problem)…it's, like that, no? you don't like it

N: no, I don't like it.

D: ok

N: I don't know why. like um…

D: um

N: no no no (refers to using the small rake which seems not so useful compared with the ruler in smoothing the sand as desired)

D: no? um, ah. I can put in these black ones.

N: ahhh, its so difficult (speaking to oneself, refers to smoothing out the sand)…we are putting all of them, in the…in the right part right? so…

D: in the right part?

N: I think that-

D: ah you want in the…

N: no no no no, I think it's nice but, I think that intuitively, we are like…creating a void

D: again

N: towards these two

D: same topics (with some dissatisfaction)

N: so we are somehow, doing similar thing to the density ones, in one…point

OB-Y: ahhhh

N: we are actually combining the density and the diagonal in…

D: I don't know what to…

N: in this one. no?

D: but eh…but we have more families no? no (holds the rocks examining possible positions and negates them)

N: yeah but I don't know if we want to put it or not…

D: eh I don't know what to do with this one…

N: ok.

D: (speaks Japanese: ok desu, translation: ok?)

N: but, these stop ehh being couples, no

D: they stopped being couples? why? maybe these…these two are too far away? (points to front rightmost couple)

N: because I think like the distance between are not, it's not right

D: maybe those two are a couple, but maybe these ones need to be…far away, let's, let's try. No? so that…those two..

N: yeah, these us, these two are working but for example this and this (refers to back rightmost two couples) are not so understandable, maybe-

D: no?

N: they could, be understood as a group. Because like the color is too similar,

D: ok so then-

N: and they are too close (means that a group of two couples seems to be formed, which is undesired). Like the distance between these ones and these ones are not so…

D: and if we remove, for example these ones? (refers to the left couple, out of the two under discussion)

N: ok, actually I put it this way I put…

D: no no no but eh…now do y-, you are, you understan-, you still understand as a, as a couple right?

N: yes

D: then…I put it here?

N: hmmm

D: no? can I try?

N: ah yes

D: yes?

N: do you want from….

D: more couples? now we have five

N: it's fine

D: (confirming) five is fine? hm

N: I think I like it, five (separating the rocks on table into subgroups while talking)

D: these two are nice, but they are similar to those big ones no? (similar to the dark couple in the middle front of the tray). These small ones…

N: where?

D: I don't know…and with the, with the other group, or…

N: I want, I don't know why but I want-

D: (expects N's words) those two alone

N: leave these ones alone

D: like they are running out of, running from the party, 'uh, this this kind of…'.

N: no because they are too beautiful

D: yeah its true its true I agree

N: because I really like the…the texture of these ones

D: and to…

N: so actually this is like the public (refers the group of couples in the right of tray) for this (as opposed to the couple at the left which "ran away") (laughing). Like the main…

OB-Y: D what is the most interesting part of the composition for you?

D: hmmm, um um um, I mean l like the colors, like the couples, and the, the intense of the composition of eh…I don't know, it's similar to before no? There's like a density, and…kind of a void, and then, but I think it works…well , kind of two that are…there and then, these ones kind of are together, but not grouped like in the…It was the thi-, the second one no?

OB-Y: second one, hm

D: second one maybe everything was very…no? very…

OB-Y: yeah, condensed together

D: condensed, and here it's like 'ok there's a dance of rocks here, those one are…going for drinks or something…and then (everyone laughing). No but if if I'm eh the, no? if we…think like in…there's a, eh, eh density but in, not in mass, but kind of in…movement, or in…no?

OB-Y: ahhh

D: in…dynamism, no? it seems like there's some dynami-, some dynamics going on here and then, there's a…quieter space and…eh…those ones that also with the form which is kind of a pyramid, they are very kind of, ehhh, taking their place these one, no? these ones, which is

like a very…big base, and kind of pointing up so, they feel like very grounded for me, these two, I don't know. What do you think N?

N: yes

OB-Y: what do you think?

N: I, I was wodering, I agree, but now I was wondering if eh, we are, eh making a…a very clear…direction, in this one also (refers to the diagonal directionality of the whole composition, shows the diagonal direction with a hand gesture)

D: yeah, might…mm I think if-

N: if we want to keep it, or if we want to…to for example if we…put another two, or another two other couples or another couple of these ones…

D: to try to lose the diagonal (completes N's thought), ah that one..

N: (tries to hold another candidate couple above the tray to test position) but it's the-, it's not working right?

D: ehhhh, yes. I think-

N: it's not working

D: I think it's like, it's true that…we go for the longer…direction, which is the diagonal, and..we kind of, the moment you play with that one, it becomes more dynamic.

OB-Y: ahhh

D: I think

N: yes

D: so if we, if you start to play with…these….ehh borders (refers to planes parallel to the viewer, shows with hand gesture) I think, everything is more kind of…standing, but the moment you take this (referring to a plane which is diagonal to the viewer, in contrast with the parallel ones), shows by hand gesture)

N: yes

D: it's kind of…breaking a little bit the…

N: yes

D: no? it's more dynamic this than this.

N: so for example, if you experience the-

D: I don't know why we do it…

N: like the garden walking here (shows a possible route through the garden with fingers), I guess like the…the diagonal, ehhh mm, composition, allows you to have like deep, more diverse ehhh

OB-Y: ah routes

N: visions and routes in the…as things inside the garden

OB-Y: hmmm

N: so…because if like yeah (shows a parallel rectangular grid with hand gesture), like if there is like a grid like Los Angeles or something like that (laughs), like the, the street is always like the same vision, like there is no surprise

OB-Y: right

N: but, if you are like

D: yeah but maybe-

N: maybe like a person right here, no? (points to a place in the tray)

D: yes

N: can have like…different…ehhh

D: (mumbles)

N: very diverse

D: maybe we can make it like eh…because these ones

N: some very different…*inaudible*

D: a- all of them are…if, if we make like kind of the grid one, it becomes suddenly…hmmm more about the rock than the composition I think, no? or something like eh, like here they are working together, but suddenly the moment you apply a very…strong geometry to what you're doing, or…space them, no? ehhh, I'm sorry (apologizes for touching the camera holder)

OB-Y: ahhh, it's ok

D: ehhh, equeally, suddenly it becomes more about, uhhh no? about order, or about ehh

OB-Y: ahhh, individual elements or…

D: yeah, instead of a group no? if we make, like if you over…ah maybe it's…also…similar with other-

N: you want to try it?

D: yeah, but maybe, maybe it's fine I think (speaks Japanese: daijoubu, translation: it's ok).

OB-Y: hmm

D: we can, this one I think it's…

N: it's fine

D: it's ok

{post-activity interview, 48:25}

OB-Y: ok, I want to ask you-

N: yes

OB-Y: think about a title for this one, one sentence, in your head – don't say. After you have it, then say, I don't want you to affect each other's…(laughing) yeah

N: ok

D: ah me too

OB-Y: you too?

D: yes, but because we've said before

N: yes…(laughing)

OB-Y: is it the same?

D: (laughing) I don't know

N: for me it's "dancing couples"

D: ah "rock dance"

OB-Y: "rock dance"? ok!

N: "dancing couples"

D: but its…kind of the same, I think

OB-Y: ahhh it completes (each other)

N: ah I like more yours (D's)

D & OB-Y: (laughing)

D: sorry (touches equipment by accident)

OB-Y: ah it's fine, don't worry don't worry. Woooow, wow wow wow, that was very nice!

N: (laughing)

OB-Y: ok, that was the last one

D & N: ok

OB-Y: ah, so…ummm, just one last question: how, how was it, like compared with how you usually work, what do you think?

D: hmmm

OB-Y: this kind of process of making something, compared with, when you design an apartment of a building or something like that?

D: (speaks Japanese: douzo, translation: go ahead first)

OB-Y: ladies first

N: (laughing) don't worry. For me, the most fun of this, is that somehow, like the big difference of between having an apartment or having this kind of rock garden, is that it has not program

OB-Y: ah

N: so only const-…like the…how you play with the element, is more direct, in this kind of game…also like (criticizing oneself) 'game' like, process

OB-Y: yeah yeah yeah, it's also a game

N: because…it's not only…thinking about, for example, very functional or technical issues, of…maybe somehow like restrictions or constrains when you are designing. But here, ehhh, like was very very direct, the way to interact with the physical element

OB-Y: yeah

N: but maybe…maybe if we are designing (an) apartment for example, ehhh, there's like a lot of discussion on the background…umm

OB-Y: ahhh

D: yeah, all the…or kind of, we are used to…like for designing for us it's very usual to have eh, kind of vectors or rules somehow, that come from the climate, from how is it going to be used, or the money, or the material, or the expectance temporality of what you're doing

OB-Y: yeah

D: so here, I think everything is so…I mean there are some rules but, they're so…kind of free

OB-Y: yeah, extremely free

D: while for us…for me at least, it's, has been difficult, it's 'ok, from the beginning, let's set some rules', no? let's eh…or let's think about the concept first. Because maybe when we design its more about, 'ok, we have all these ingredients-' no?

OB-Y: yeah

D: 'that…the whole…reality of the project has, and then we start to prioritize once, and maybe another once (time), because you cannot always eh, get everything no? like eh, you start to prioritize, 'ah so ok, let's talk about this part of the network, and then this one we can deal with it later and so on'

OB-Y: ahhh

D: but here it's kind of, you have to make you own…rules

OB-Y: yeah yeah

D: which…it's also, it's also fun, but different from what we….no? are used to probably.

OB-Y: wow, I'm really happy.