THE RELATIONSHIP BETWEEN INTERACTIVE IMAGERY AND SHARED MENTAL MODELS IN DESIGN ENVIRONMENT

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ABSTRACT

THE RELATIONSHIP BETWEEN INTERACTIVE IMAGERY AND SHARED MENTAL MODELS IN DESIGN ENVIRONMENT

This study explores the relationship between interactive imagery and shared mental models in a design learning environment. The thesis focuses on design, design learning, and the cognitive components of design. In this research, conceptual project development processes of Izmir Institute of Technology third class architecture students from a studio where four instructors gave desk critiques on a rotational basis are examined. Within the scope of the study, interviews were conducted with four students and four studio instructors. The process was analyzed and interpreted with the collected data and interviews. It is argued that interactive imagery and shared mental models, which are shaped in the studio's desk critiques, juries and panel reviews, affect the students' conceptual project development. It is possible to conclude that if there are more than one studio instructor giving desk critiques on a rotational basis, students may have both advantages and disadvantages.

Keywords: Design; Design Learning; Design Cognition; Representation; Reasoning; Interactive Imagery; Mental Model

ÖZET

TASARIM ORTAMINDA ETKİLEŞİMLİ İMGELEM VE PAYLAŞILAN ZİHİNSEL MODELLER ARASINDAKİ İLİŞKİ

Bu çalışma tasarım öğrenme ortamında etkileşimli imgelem ve paylaşılan zihinsel modeller arasındaki ilişkiyi araştırmaktadır. Tez kapsamında, tasarım, tasarım öğrenme ve tasarımın bilişsel bileşenleri üzerine odaklanılmaktadır. Araştırmada, İzmir Yüksek Teknoloji Enstitüsü (İYTE) üçüncü sınıf mimarlık bölümü öğrencilerinin kavramsal proje gelişim süreçleri incelenmiştir. Araştırma kapsamında, dört öğrenci ve dört stüdyo yürütücüsüyle görüşmeler yapılmış ve onlardan veriler toplanmıştır. Toplanan veriler ve yapılan görüşmeler ile süreç analiz edilmiş ve yorumlanmıştır. Çalışma sonucunda, tasarım öğrenme ortamı olarak stüdyodaki masa kritikleri, jüriler ve panellerde gerçekleşen etkileşimli imgelem ve paylaşılan zihinsel modellerin öğrencilerin kavramsal proje gelişim süreçlerini etkilediği öne sürülmüştür. Bu çalışmada olduğu gibi, birden fazla stüdyo yürütücüsünün rotasyon yöntemi ile yürüttüğü stüdyoda, öğrencinin daha fazla etkileşimli imgeleme ve daha fazla zihinsel modele maruz kalmasıyla, hem avantaja hem de dezavantaja sahip olabileceği üzerine yorum getirilmiştir.

Anahtar Kelimeler: Tasarım; Tasarım Öğrenme; Tasarım Bilişi; Temsil; Akıl Yürütme; Etkileşimli İmgelem; Zihinsel Modeller

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CHAPTER 1

INTRODUCTION

1.1. Problem Definition and Scope

Design process is a cognitive activity that can vary depending on the conditions, people, and design parameters of a particular design situation. Design evolves as a synthesis of the parameters involved in the process. It is, therefore, possible to define each design process as unique. The difficult and complex structure of design makes it difficult to learn and teach the design process.

Designing and learning are closely related styles of interrogation. In design, learning activity is based on ‘learning-by-doing’ (Schön and Wiggins 1992). Among the aims of design education are the acquiring the ability to "realize cognitive behaviors" (Finke, Smith and Ward 1992). Design learning consists of getting acquainted with these behaviors (Oxman 2001).

In studies on design learning, Schön (1983) and Goldschmidt (2005) explain design learning through three main components. Especially in the studies on design studios, which are the fundamental learning environment, these components are defined as instructor, student, and representation (tool). According to these studies, design learning is shaped with these components.

According to Schön (1983), every profession has a set of esoteric knowledge. This body of knowledge, which may be verbal or practical, is used during the practice process of the profession (Schön 1983). Esoteric knowledge, which is learned in action, is ‘tacit knowledge’. This knowledge is referred to in the literature as ‘procedural knowledge’ (Crowder 1993). According to Eastman (2001), generally, studio instructors present this ‘tacit knowledge’ in design studios. A similar argument belongs to Schön. Schön (1983) claims that design instructors are coaches who take initiative. They have both conceptual and operational knowledge.

According to Schön (1983), design studio is the environment where the ‘procedural knowledge’ is learned through interactions between a novice (student) and a coach (instructor). According to Schön (1983) this learning style is defined as "reflection-in-action". Novice learns the procedural knowledge in this process. Experiences in this process are ‘reflective practices’ (Schön 1983).

Schön (1985) explains states that students learn through communication facilitated through verbal and graphical language used by the student and the instructor. According to Uluoğlu (1990), these verbal and graphical expressions complement each other in communication through expressions and grammar.

Goldschmidt (2005) argues that people have acquired a body of knowledge in their previous education and life experiences and any field-specific knowledge and skills are based on this body of knowledge. Moreover, each person has his or her own cognitive and personal characteristics (Goldschmidt 2005). When faced with a design task, the designer solves design problem by using this knowledge and characteristics. Therefore, each person creates a unique solution space (conceptual space) in the design process. If this process is experienced in the context of an instructor-student desk critique in the studio, both student and instructor develop design process through their knowledge and personal-cognitive characteristics (Goldschmidt 2005). These two components (instructor and student) are important factors affecting the design process.

The third component of design learning process is representation (tool). According to Akın (1986), representation is an important part of a physical intuition and design synthesis. Representational activity has an important role in design problem solving and it is used externally in graphic domain or internal imagery (Akin 1986). According to Akın (1986), there are two types of representation. One of them is external representation as stimuli. The other is internal representation that occurs in mind as the result of external and internal representations. Therefore, representation is a tool for shaping thought (Akin 1986). According to Goldschmidt (1997), internal representations are the basis of cognition. Internal representation is the visual state of the image of an idea or object in memory. Internal representations can be seen with the "mind's eye" (Goldschmidt 2017).

When mental representations are organized in such a structured way that identify and predict objects, conditions, phenomenon, and people, they are called mental models

(Goldshmidt and Surasky 2011). Mental models are systems that interact and develop with environment or the mental models of others. These mental models are shaped by experiences and knowledge (Goldshmidt and Surasky 2011). In many disciplines language is the dominant medium in the transmission of mental models and construction of shared mental models among different individuals. In the design studio environment, the interactive communication between a student and an instructor facilitated through verbal and visual representations targets at achieving a shared mental model. In design learning, different from learning in other fields, visual images are irreplaceable to create common mental model (Goldschmidt 2017). In the design process, the interaction of representations and shared mental models brings new knowledge and creative results (Rouse and Morris 1986). Therefore, it is possible to say that in design learning environment, representation has an important role and it is one of the main components in design learning process.

In this thesis, the argument is that studio learning environment is a loosely structured collaborative learning environment supported through external representations facilitating the construction and sustainment of shared mental models. And also, this learning environment is a cognitive system including students, multiple instructors, external representations and internal representations.

The interaction of the three components shapes the design learning process together with cognitive abilities such as thinking, reasoning, mental and interactive imagery. Researchers such as Schön (1983) and Goldschmidt (2005) have commented on momentary interactions in their work on these three components, cognitive abilities, and the design learning process. In their studies, the momentary product and process occurring by momentary exposure to instructor's mental models are examined. However, in design studios, the conceptual development phase as a design learning step is an elongated process and not a momentary episode. Therefore, in this thesis, the aim is to examine how this interaction happens in elongated process and the role of these abilities in the process is investigated. This study examines four case studies in a design studio with more than one instructor to understand the construction of shared mental models through visual and verbal communication throughout the whole semester. It especially focuses on how a student’s mental model of a design situation keeps changing or remains unchanged in a design studio where students take critiques from different instructors.

1.2. Research Focus and Questions

This study explores the role of cognitive abilities in the design process and the relationship of these abilities with instructor-student-representation in the design learning process. The study focuses on the conceptual development process of third year architecture students' projects. The study consists of retrospective analysis and interpretation of results of desk critique, panel review and midterm jury performed by four architecture students and four instructor.

In this context, the research questions are:

1. How does interactive imagery facilitate construction of shared mental models in a design learning environment?

2. How does the interactive imagery that occurs in the desk critique process performed by more than one instructor through the rotation method affect the student's conceptual space (solution space)?

1.3. Method

The research carried out in this thesis is of qualitative nature, using qualitative data collection strategies to examine an elongated design learning process focusing on interactive cognitive practices within the design studio environment.

In this thesis, case study was used as a strategy of inquiry. The purpose of this case study is to present a concrete example to explore the research question. There are four different cases in this study. These cases examine the design learning process in the studio environment. The study is based on retrospective accounts of students and instructors. In this thesis, data gathering began at the end of the project development. The cases were investigated after the phenomenon.

During the research process, semi-structured interviews were used to collect students' and instructors' accounts of the design process for each studied student. In these interviews, open ended questions were used to ensure that the accounts would provide rich and detailed data. In the interviews, visual and verbal documents related to students' projects produced by students and instructors during panel and desk critiques

were collected. The collected data and documents were analyzed and interpreted in the light of literature studies.

1.4. Chapters' Summaries

Chapter 2 presents a literature review related to three main topics: design, design learning, and cognitive components of design. In cognitive components of design section, the relationship of representations and reasoning in design environment is explained. Moreover, external and internal representations, representations as inspiration, representation as mind-eye-hand interaction, mental imagery, interactive imagery, knowledge creation, recalling design knowledge and shared mental model are also introduced in this chapter.

In Chapter 3, the research methodology and the research approach used in this thesis are explained. This chapter includes one main section that discusses the relevance of case study for this research. This section includes four sub-sections, i.e., Participations, Procedure, Materials, and Interpretations.

Chapter 4 introduces the four cases of the study and their discussion. In each of the cases, the conceptual development processes of students' projects are studied in detail. The relationship between design learning and interactive imagery facilitated through shared mental models is examined. Following the detailed descriptions of cases, a general discussion is presented at the end of the chapter.

In Conclusion the summary of the thesis, implications and significance of the study and limitations are explained. In addition to these, future research and works of the study is presented.

1.5. Contributions of the thesis

The present study aims to explore how interactive imagery facilitates construction of shared mental models in a design-learning environment and how interactive imagery occurring at desk critiques performed by more than one instructor affect students' conceptual space (solution space). The purpose of this study is to

present an overview of the design learning processes taking place in the studio environment and to contribute to the views of designers about the process.

CHAPTER 2

LITERATURE REVIEW

This chapter presents an overview of the literature on three main subjects which are “design”, “design learning”, and “cognitive components of design”. It starts with a discussion on design, design process, and design problem as a cognitive activity. In the following section, studies related to design learning are reviewed. In the last section, cognitive components of design thinking are reviewed in relation to design learning and design process. This last section consists of two sub-sections. The first cognitive component to be introduced in this section is representation. Representation refers to both external and internal representations and is discussed as a medium of inspiration and as mediator between mind-eye-hand. Reasoning is reviewed as the second cognitive component. This section is divided into five sub-sections in itself. These sub-sections are mental imagery, interactive imagery, knowledge creation, recalling design knowledge, and shared mental models.

The aim of this chapter is to inquire into the question of “How does interactive imagery facilitate construction of shared mental models in a design learning environment?”

2.1. Design

Designing is the process of thinking, developing, and objectifying the images that are rendered in the mind. Design is possible with the construction of the concepts in mind, the transfer of these concepts in a language (representation), and their reproduction. Design is defined by design researchers in different ways. Some have defined design as a “problem solving process” (Newell and Simon 1972), others as a “knowledge-based activity” (Coyne, et al. 1990), or a “cognitive activity” (Akin 1986), or as “reflection in action” (Schön 1983). Based upon the content, the design has numerous definitions. While some researchers define design as a noun, some define it as a process. Design is both a product or to a process (Lawson 1986).

The difficult and complex structure of design makes it difficult to learn and teach the design process. According to Lawson (1986), design involves a complex mental process that can bring together and synthesize a lot of knowledge and enable the synthesized knowledge to turn into a concrete product.

In order to define, learn, and teach design, it is important to discover what is in the mind of the designer. The emergence of cognitive psychology in the 1960s suggested a method for both the identification of design and the study of mental activity occurring during the design process (Eastman 2001).

Arnheim (1969) defines cognition as all mental operations related to the retrieval, storage, and processing of knowledge in addition to sensory perception, memory, thinking, and learning. Some researchers working on the cognitive processes of designers such as Akın and Akın (1996), Lawson (1986), Kolodner and Wills (1996), Schön and Wiggins (1992), Schön (1985), Oxman (2002), Cross, Dorst and Roozenburg (1992), Goldschmidt (1994), and Liu (1995) argue that the basic structure of design is 'seeing-drawing-seeing' and ‘a reflective speech’. From the point of view of these researchers, design is the process of bridging the problem and solving problems and finding new problems rather than solving the problem. Moreover, these researchers point out that design is too complicated to be reduced to just problem solving or knowledge process in the design process.

Design problems are referred to in the design literature as "ill-defined" problems (Rittel and Webber 1973, Simon 1969). For this reason, some researchers focus on the process components to examine the design process (Hitchcock 1989). Some researchers suggest that design is decomposed into smaller chunks in order to transform the "ill-defined" design problem into "well-defined" (Alexander 1964). Simon (1969), one of these researchers, deconstructs design problems into sub-targets. According to Simon (1969), designer produces solutions for each sub-problem. Neglecting mutual relationships between sub-problems causes failure throughout the whole process (Simon 1969). Similarly, Akın (1986) divides design activity into constituent parts and defines the whole process in reference to three activities. According to Akın (1986), these activities are searching, representing, and reasoning.

Schön (1983) describes the relationship between designers and sketches as a cognitive aspect of design. His work has an important impact on the studies of design

cognition. According to Schön (1983), design activity is a "reflection-in-action". This approach is often used by design researchers to interpret design and design activity (Dorst and Dijkhuis 1995).

2.2. Design Learning

Designing and learning are closely related styles of interrogation. In design, learning activity is based on ‘learning-by-doing’ (Schön and Wiggins 1992). According to Schön (1983), design depends on the ability to identify the features required by the modern world. However, beginning designers do not have this ability. The knowledge provided by these abilities cannot be conveyed to them by verbal expressions. The reason for this is that design has a specific meaning in the operational context. In other words, the conceptual meaning of design becomes meaningful again in the operational process (Schön 1983). The meanings of words used in design contexts are related to the design movements to which they are attached (Schön 1985). According to Schön (1985), the importance of design movements depends on the language used to reflect them. For this reason, the "design language" is an important part in reflection-in-action process (Schön 1985).

Schön (1985) argues that a student, who first meets with the design studio, s/he meets a new language that s/he did not know in her/his past life. Moreover, the aim of the education process is mainly to teach this language (Schön 1985). Schön's approach to design teaching and design learning is similar to the approach of defining the design process (Schön 1985). According to Schön (1983), design instructors are coaches who take initiative. They have both conceptual and operational knowledge (Schön 1983) which is explicated during the conversation in the context of design studio.

Goldschmidt (2005) offers a similar argument. She claims that in design studio two different types of knowledge, which are creativity and technical knowledge, are used. According to her, creativity is a kind of knowledge that cannot be taught but can be described and guided, whereas, technical skills are a kind of knowledge taught in the studio.

At the beginning of the design learning process, design students start to learn design process as a "novice". However, they do not have any conceptual or procedural

knowledge about design (Schön 1983). They do not know the specific meanings of the esoteric conditions of both the operational movements and the related design word knowledge (Schön and Wiggins 1992).

According to Schön (1983), every profession has a body of special esoteric knowledge. This body of knowledge knows is used during the practice of the profession. The body of knowledge may be verbal or practical (Schön 1983). Esoteric knowledge, which is learned in use, is ‘tacit knowledge’. This knowledge is referred to in the literature as ‘procedural knowledge’ (Crowder 1993). According to Eastman (2001), generally, studio instructors present this ‘tacit knowledge’ in design studios.

Schön (1985) explains how students learn in the process, through communication between an instructor and a student, with the help of verbal and graphical language that externalized during communication. According to Uluoğlu (1990), in communication through expressions and grammar, verbal and graphical expressions complement each other.

According to Schön (1983), there are three ways to acquire ‘procedural knowledge’ in learning design. Schön (1983) defines the first as self-instruction. According to Schön (1983), second occurs in the context of real world situation, which is ‘apprenticeship-learning’. However, this last is unproductive and has adverse real world conditions (Schön 1983). Schön (1983) defines the third way in the context of virtual world (generally design studios), it is ‘novice-coach’ as ‘off-line’. According to Schön (1983) this learning style is defined as the "reflection-in-action" process. Novice learns the procedural knowledge in this process. Experiences in this process are ‘reflective practices’ (Schön 1983).

Goldschmidt (2005) argues that two types of learning take place in the design studio. These learning types are ‘conceptual learning’ and ‘professional learning’. According to Goldschmidt (2005), the design process, after determining the problem, is shaped by the designers through interpreting the problem. However, the designer is not objective in this interpretation process. The reason for this is that any field-specific knowledge and skills are based on the ‘background knowledge’ that people have had in their previous education and life experiences. Moreover, each person has his or her ‘own notes’ with their own cognitive and personal characteristics. When faced with a design task, the designer as ‘α - independent input/design modifier’ thinks through the

process together with the ‘background knowledge’ and ‘own notes’. If this process is experienced in the context of an instructor-student criticism in the studio, the instructor as ‘β - instructional Input’ takes the ‘background knowledge’ and ‘own notes’ together in the process. These two inputs (α and β) are important factors affecting the design process. The level of utilization of these two inputs and the level of interpretation of knowledge from them determine the learning style. Conceptual learning is concerned with concept identification and shaping. Professional learning is concerned with using field-specific knowledge to solve a design proposal or concept (Goldschmidt 2005). Actually, ‘professional learning’ stated in this work by Goldschmidt (2005) is about the ability to use ‘procedural knowledge’ (Crowder 1993).

Design learning process is not linear (Lawson 1986, Dorst 1995). There are overlaps between design stages. Whatever knowledge ‘learning-by-doing’, ‘professional learning’, ‘conceptual learning’ or ‘reflection-in-action’ includes an automatic learning situation due to the nature of design activity (Schön and Wiggins 1992). In other words, automatic learning can be defined as the acquisition of architectural knowledge within the framework of the individual's design activity in her/his own design action.

According to Uluoğlu (2000), design can be taught and learned through interaction between designers. Therefore, design is not just about "doing" an action. Design activity is based on cognitive abilities. In the design process, cognitive abilities guide the process. These abilities, which include competences such as reasoning, thinking, learning, can be different in each person. According to Goldschmidt (2005), cognition is based on background knowledge (people have had it in their previous education and life experiences) and own notes (personal characteristics). This approach explains why design cannot be taught with existing knowledge and skills (Uluoğlu 2000).

2.3. Cognitive Components of Design

Design which is a cognitive activity, involves different mental stages (Akin 1986). Designers learn these mental stages by experimenting, thinking, intuiting, and doing. Among the aims of design education is to acquire the ability to "realize cognitive behaviors" (Finke, Smith and Ward 1992). Design education helps in getting familiar and using these behaviors (Oxman 2001).

Designers work in a process that proceeds from abstract and ill-defined problems (Dunbar 1998). The cognitive system has extraordinary abilities to deal with ill-defined problems such as design, and it provides to solve them creatively (Goldschmidt 2017).

There are various studies in the literature on these abilities and their relation to design learning and design process. According to Oxman (2001), some of these studies are “mental imagery and visual reasoning” (Kosslyn 1975), “analogical reasoning” (Holyoak and Thagard 1995), “remembering” (Schank and Abelson 1977), “visual design thinking” (Goldschmidt 1994), and “metaphorical reasoning” (Lakoff 1994). The design problem is solved by these skills, which are basically thinking, learning and reasoning, and by the tools supporting them.

One of the most important tools in the problem solving process of design is to create a ‘language’. At this point, representation plays a very important role. Representation is the basic component of this process both as a mental activity and as an externalization of this activity (Goldschmidt 2007).

According to Goldschmidt (2017), design process contains some stages. These stages are acquisition of knowledge, selection of appropriate knowledge, association or transformation, production of alternative synthesis and formation of new design ideas (Goldschmidt 2017). As in the actual design environment, the design studio has similar stages in the design process (Suwa and Tversky 1997).

While seeking solutions to design problems at hand, students are transforming their knowledge and experiences they have learned in combination with other interactions in the process (Goldschmidt 2017). A synthesis of existing knowledge and new learned knowledge emerges in instructor-student critiques in design studio. The resulting product is an example of interactions within the process. The design feedbacks that are carried out to transfer the mental models of the instructor and the student to each other usually take place with visual representations.

2.3.1. Representation

Representation is an important component in design and cognition (Oxman 2001). Representation is defined as the model of things represented by the expression ‘something that stands for something else’ (Johnson 1998, 262). Akın (1986), defines

representation as a phenomenon that organizes objects and processes. According to Akın (1986), representation creates something completely new for the design and he argues that during the design process, the representation stands for an object to be built. The designer carries out his/her thoughts and forms through representation (Akin 1986).

The meaning of the affix‘re-‘in the word of representation can be interpreted in two ways. Firstly, designer re-represents something which is in his/her mind through externalization. Secondly, the things that are externalized become internalized again in the mind of the designer. The designer needs representations to describe the image of the design in his/her mind and to communicate with himself/herself and others. According to Schön (1983), designers use representations for design, communication, and criticism. They use representations to both solve these problems and create a language (Oxman 2001). According to Akın (1986), representation is an important part of a physical intuition and design synthesis. Representational activity has an important role in design problem solving and it is used externally in graphic domain or internally in imagery domain (Akin 1986). According to Akın (1986), there are two types of representation. One of them is external representation as stimuli. The other is internal representation that occurs in mind as the result of external and internal representations. Therefore, representation is the tool of shaping thought (Akin 1986). In other words, representation is not only a passive mechanism that externally displays what the mind contains, but it is actively guiding design (Akın and Moustapha 2004).

2.3.1.1. External and Internal Representations

The relationship between external and internal representations should be examined to understand the importance of representations in the design process (Johnson 1998). Internal representations and external representations are coupled and enable a complementary cognitive system (Figure 1). External representations are either externalized versions of internal representations or modifications of already existing representations. Everything we perceive with our sense organs, such as visual images, speeches, writings, is an external representation. In general, external representations in the field of design are plan, section, elevation, 3D or 2D images, models, diagrams, graphics, digital representations, or sketches. Unlike internal representations that occur

in the mind during design, external representations also allow interaction with other persons and teams involved in the design process (Brereton 1999).

According to Goldschmidt (1997), internal representations are basic components of cognition. Internal representation is the visual state of the image of an idea or object in memory. Internal representations can be seen with the "mind's eye" (Goldschmidt 2017). According to Goldschmidt (2017), the internal representations can never be exported as an exact reflection of the image in the mind. However, external representations that “download” internal representation from the mind, are the closest representations to internal representations. In design, designer uses external and also internal representations (Goldschmidt 2017).

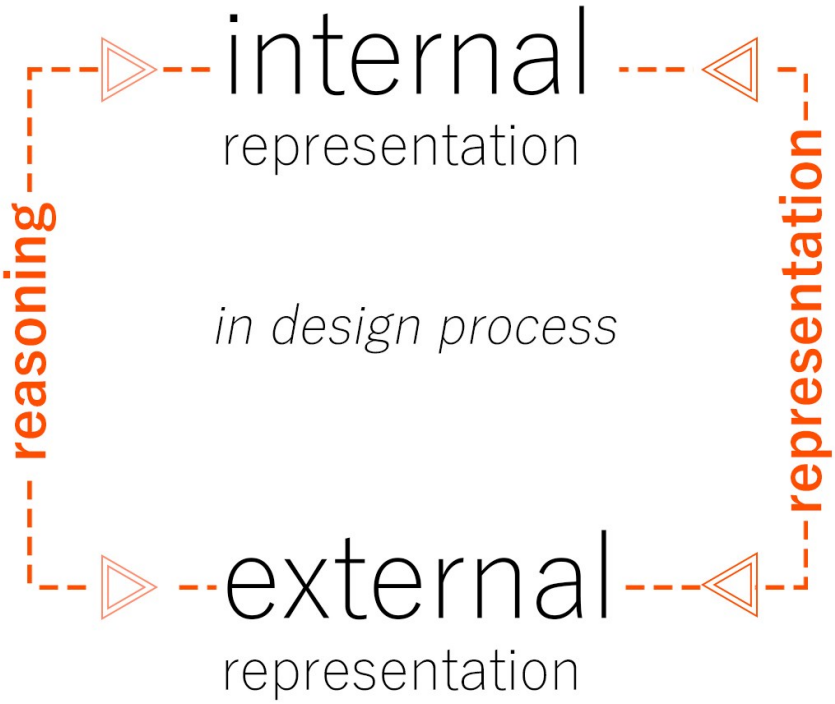


Figure 1: The relationship between external and internal representations

In the design process, internal representation and external representation are concepts that both reflect and influence each other. At the same time, it is possible to say that they are part of a system which is constantly changing into one another. Following this line of argument, this study question how external representations support and/or enable the process of design thinking and learning in the studio environment during interactions among a student and multiple instructors.

2.3.1.2. Representation as Inspiration

Inspiration is searched for actively by the designer. In fact, the knowledge which constitutes the basis of an inspiration is called in the designer's own memory. It is the stimulus (in the external environment) that allows the knowledge in the memory to be recalled. According to Goldschmidt (2017), the source of inspiration is diverse and can be within-domain or between-domain. It can be verbal or visual. However, the source of inspiration in design is very much related to visual images because the product of the design process is a visual product (Goldschmidt 2017).

Experience, objects, and ideas that are in the past and present can be a source of inspiration for an architect (Lasdun 1976). In design field, because inspiration is transmitted through visual images, experienced designers keep the image stock in the "wait state" and they touch these collections when appropriate (Keller, et al. 2009). For example, according to Curtis (1986), Le Corbusier, who has a large collection of images in his memory, puts these images out condensed into sketches and then the idea emerges (Curtis 1986).

In the design process, it is possible to mention that there is an interaction between external representations (especially sketches) and knowledge that designers "import" from other domains (Lasdun 1976). The "new" idea or product created with the help of the imported knowledge is described as the result of source of inspiration. Anything that is external or internal in the design process, influence the process. These images or knowledge are often described as "inspiring" and they have significant effects in the creative design process (Goldschmidt 2017).

2.3.1.3. Representation as ‘Mind – Eye - Hand’ Interaction

Designer has many representation tools for both himself/herself and others to show an image which occurs in his/her mind or to construct an image. These are sketches, technical drawings, 3D drawings, digital images, models, or words. All of them support the image.

The most common representation method in design is sketch. The reason for this is that the nature of the sketch overlaps with the image as they are both blurred and

vague. In the design process, the image is uncertain, blurred and undefined. For this reason, it takes time for the image to become visible. The vague nature of sketch is very suitable for this situation. Sketching is fast enough that it does not interrupt the flow of thinking. Goldschmidt (2017) argues that sketch is a ‘laboratory’ where the designer can test solutions.

Goel (1995) investigates the sources in sketching in an experimental study. According to Goel (1995), the sources, which are used in the serial sketch process, are obtained from either long-term memory or previous solutions. Each drawing in the sketch process includes both a syntactic source and a semantic source. Sketching enables changes in design along lateral and vertical transformations. The lateral transformation implies a differentiation of thought. Vertical transformation suggests a change of an idea by way of detailing. In these transformations, the freehand sketches add creative and exploratory extensions to the designer's problem solving. Thus, lateral transformation reduces the risk of fixations that may occur at the beginning of the design (Goel 1995). In the design process, serial sketch activity aims to provide new options. This repetition comes with continuous feedback. This process is basically the stage that Goel (1995) refers to as a vertical transformation.

Sketches increase memory activation that is an important factor in creative thinking (Gabora 2010). While the designer conveys the representation in his/her mind, s/he does not aim at conveying the exact same image as in her/his own mind. Because it is a sketch, it does not describe a finished image. It is a tool for discussion, thinking, and exploring. Sketch is a tool in which designers communicate and also chat with themselves (Schön and Wiggins 1992). For this reason, the designer has the possibility of finding something different and interpreting it differently on each line drawn. Each line can invoke a different idea and object (Suwa and Tversky 1997). In other words, sketches provide "feedback" to the designer. Thus, it creates a source for the designer's next step (Schön and Wiggins 1992). In this context, the sketch is an ‘external memory’, not only as tools of thinking and communication but also of mental images (Finke 1993).

The two-way interaction between sketches and concepts in mind describes visual thinking (Akın and Moustapha 2004). In visual thinking, representation does not exist only by creating an external representation with the production it exports. It also

establishes the connections between the mental structure, intuitive processes, and physical perceptions that occur in the mind. Representation keeps a record for the growing chains of thought (McKim 1972). Thus, the thought becomes visual and it creates memories of the process (Goldshmidt and Porter 1999).

According to Frascari (2011), representation is one of the cognitive components that coordinate the relationship between memory, thinking, and imagination. Frascari (2011) argues that when representations are externalized, load of memory relax. Thus, it can reduce the continuous memory control and limitations of memory (Frascari 2011).

Representation as a memory tool is both a remembering tool and a forgetting tool (Goldshmidt and Porter 1999). With external representations, the designer creates a mind that can nurture or change his/her own thinking.

2.3.2. Reasoning

Reasoning is one of the cognitive components that determine the response of people to conditions or events (Rittel, 1987). According to Rittel (1987), reasoning is in the essence of design process and design thinking. In design, reasoning is theorized as abductive, deductive and inductive reasoning (Dorts 2011).

When looking for a solution to a design problem, designers transform their knowledge and experience they have learned and continue to learn by combining it with other interactions in the process. As mentioned in the previous section, representations have an effective role in the design process.

In the design process, visual images or representations are a very effective tool for some reasoning types. Some of these reasoning are analogical reasoning (Gentner and Stevens 1983), case-based reasoning (Kolodner 1993), and pictorial reasoning (Gero, Tham and Lee 1991).

In addition to other types of reasoning in design, visual reasoning, which includes mental imagery and visual representations, is used (Oxman 2001). According to Oxman (2001), representation which is used in visual reasoning, can be an external representation that can be matched to an internal representation and it makes the reasoning process possible. Studies on visual reasoning show that visual reasoning

interacts with external representation in the perceptual process (Schön and Wiggins 1992).

Goldschmidt (1991) argues that in pictorial reasoning, it is possible to directly access the knowledge contained in the visual images. However, it is also possible to access knowledge that they do not expressly disclose (Goldschmidt 1991). In other words, different knowledge can be obtained by reasoning with the help of visual images or representations, and different knowledge can be called from the memory.

2.3.2.1. Mental Imagery

According to Arnheim (1969), mental images are loyal copies of objects in real world. These loyal copies are "eidetic images" in the words of Arnheim that are found in memory (Arnheim 1969). According to Athavankar (1997), Arnheim (1969) states that mental imagery is one of the means for design thinking. Similarly, Mc Kim (1972) claims that mental imagery is part of visual thinking. Sommer (1978) refers to mental imagery as ‘mind's eye’ and he claims that the 'mental imagery ability' allows conversions in the mind.

According to Kosslyn (1999), mental imagery takes place with two actions. The first is in relation with perception. In other words, it is “seeing with the mind’s eye”. The second is existing mental representation which is stimulated by perception. Imagery can occur in multiple sensory stimuli (Kosslyn 1999, 83).

According to Goldschmidt (2001), images that have never been perceived before can occur through imagery. In this process, the designer works like an inventor to discover something new based on "existing things in mind".

2.3.2.2. Interactive Imagery

According to Schön (1992), sketches are used as a ‘reinterpretation tool’. The use of sketch in the design process indicates a representation world in which the mental and non-mental are in constant communication. Sketch allows reinterpretation of a thought or an object. Sketch allows detection of new features (Spankie 2009). When the line begins to be drawn, communication starts simultaneously (Schön 1983). The sketch

is included in the design process from the moment it is applied and it is metamorphosed throughout the process (Goldschmidt 1992). Every development or metamorphosis that takes place in this process is evidence of one new knowledge and thinking action (Goel 1995).

In the sketch process, imagery makes it possible to see certain point, line and sign selections as meaningful. According to Goldschmidt (1991), imagery is the essence of seeing something as something else. If this happens in the sketch process, it is “interactive imagery” in words of Goldschmidt (Goldschmidt 1991, 131). The interactive imagery allows the designer to communicate with the materials and it uses the transforming speed of sketches (Goldschmidt 2001).

Sketches are similar to the image because they can be perceived by the senses and both sketches and images can affect the mind as a stimulus. However, a sketch may not represent the same image for everyone. In other words, sketch contains more knowledge than what appears on the paper (Goldschmidt 1991). Sketches can invoke other knowledge or objects which constitute the basis of interactions between designer and representation in pictorial reasoning process and this interaction is called interactive imagery (Goldschmidt 1991).

Goldschmidt (1991) argues that in the design process, pictorial reasoning takes place in two different ways. The first is "seeing that" and the other is "seeing as". “Seeing that” is reasoning by perceiving it as an image as is. In other words, it is a reasoning that does not invoke different associations than its initial and immediate signifier. "Seeing as", in contrast, is the result of interaction with association of ideas (Goldschmidt 1991). Sketching is a process that involves both "seeing as" and "seeing that". Goldschmidt (1991) argues that sketch is a systematic dialectic.

According to Goldschmidt (1994, 165), there is a difference between “ordinary imagery” and “interactive imagery”. Images in interactive imagery are not taken directly from memory. A person can take an image of a previously perceived image in this process. In the first stage of design, the design is not yet available and it may not be detected. Thus, sketch is an interactive process of symbolic representation. Sketches allow imagery to change (Goldschmidt 1994).

2.3.2.3. Knowledge Creation

In design, there is various kind of knowledge in different domains. Knowledge that is structured according to knowledge accumulation is called “knowledge structure” (Galambos, Abelson and Black 1986). The knowledge about the design is not limited to the knowledge previously acquired. Each process and experience restructures this knowledge. Knowledge structures inform about understanding, archiving, recalling, and implementation of knowledge (Galambos, Abelson and Black 1986).

At the beginning of a new design, the first solution proposal that the designer can produce for the design problem is produced with knowledge from designer's mind (Goldschmidt 2007). It is possible to express this knowledge as internal representation. Designers often express their representations in their minds either verbally or visually. The most common visual expression tool in this process is the sketch (Goldschmidt 2007). Because sketching is a very expressive representation tool that can be produced very easily, very quickly, and with very simple means (ex: paper and pencil) (Badke-Schaub, et al. 2007). These features of sketch make it useful in the process of creating a common mental model.

2.3.2.4. Recalling Design Knowledge

When designing, a thing that does not yet consist is created, so any image cannot be created for the thing that does not exist in the mind. However, designers create an image at the end of the design process. How does the designer create these non-existent things and images?

During the design process, there are stimuli that evoke visual image or conceptual knowledge from memory and make them active in memory (Figure 2). Generally, analogical sources can provide external stimuli that are searched by designer in design activity (Casakin and Timmeren 2015). The stimuli are considered to be an appropriate source of inspiration as they can support the development and change of the design idea (Cardoso and Badke-Schaub 2011).

According to Goldschmidt (1995), designer remembers the forms found in memory with the help of stimuli, which is called recall. Most of the recall activity is

initially done mentally. In addition to that, recalling is done synchronously with an intuitive search for matching the problem in hand and stored images (Goldschmidt 1995). Knowledge stored in memory can be accessed with the help of stimuli. These stimuli can be external analogical sources. The knowledge obtained through these sources can be used to generate new ideas (Goldschmidt 1994).

In the design process, it is necessary to know the working mechanism of the memory in order to know the relation of stimuli that help imagine new things. Working memory is a mental working space where knowledge is analyzed, manipulated, and synthesized (Malamed 2011). According to Malamed (2011), when people are offered new knowledge that they did not know before, the person first searches it in the memory. When there is a match between new knowledge and memory, people recognize and define objects and concepts in reference to this memory trace. When they cannot find a match, they make inferences about this new knowledge based on the knowledge that they previously have. Processed knowledge in the working memory is transferred to the long-term memory. New knowledge becomes more memorable as the previously stored knowledge establishes a strong link (Malamed 2011).

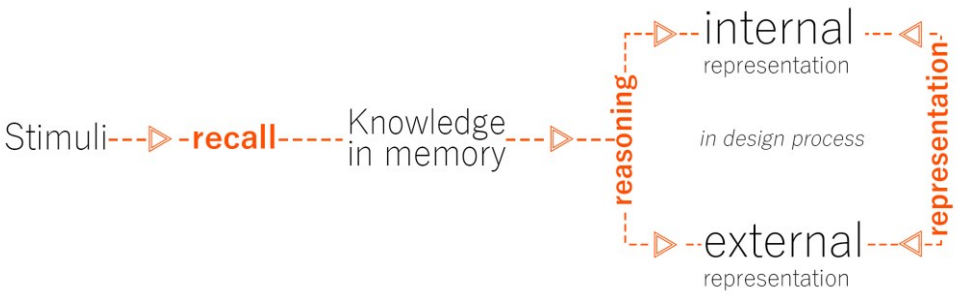


Figure 2: The relationship between recalling knowledge and representations

In design, stimuli, which help creating new knowledge, new form, and new concept, can be recalled from long term memory. For this reason, stimuli serve as a source of inspiration for a new image. In the design process, stimuli can be an image, a word, or a sense. However, designers prefer to use visual source because of reaching visual simulation (Hanington 2003). Therefore, designer uses pictorial features of the design object. Designers can do this through visual thinking and visual reasoning (Goldschmidt 1992).

2.3.2.5. Shared Mental Model

The term ‘mental model’ refers to people's ways of thinking and reasoning; mental models create simplified reality models that help us with reasoning, action, new situations, thinking, and everything (Goldshmidt and Surasky 2011). The term mental model began to be used in the literature with Craik's work on human behavior and cognition (Craik 1943). Recently, Johnson-Laird (1983) and Gentner and Stevens (1983) used term of "mental model" in their various studies.

Mental model is defined as an internal representation that provides to identify and predict objects, conditions, phenomenon, and people (Goldshmidt and Surasky 2011). Goldschmidt (2017) argues that people acts on the basis of mental models that guide behavior and thought. Within the scope of the study, the mental model is defined as internal representations that arise as a result of the interaction of designers with external representations.

Mental models are systems that interact and develop with environment or the mental models of others. Everyone has mental models. These mental models are shaped by experiences and knowledge (Goldshmidt and Surasky 2011). Especially in team work, it is important to have teammates share their mental models with each other (Gentner and Stevens 1983). Each team member has her/his own mental model in a team. However, to be effective, the team needs to share mental models. Therefore, team members externalize their mental models to discuss their views and exchange their opinions (Goldshmidt and Surasky 2011). In team work, a common mental model is achieved by shared mental models (Langan-Fox, Anglim and Wilson 2004).

In many disciplines it is possible to refer that language is dominant in the transmission of a shared mental model. However, in design, which is heavily dependent on visual images, visual images are irreplaceable to create common mental model (Goldschmidt 2017). Any study on shared mental models in design learning, therefore, needs to take into account the visual communication between instructor(s) and students.

In design process, the interaction of representations and shared mental models brings new knowledge and creative results (Rouse and Morris 1986). For example, in a design team, each team member transfers her or his mental model to other team

members through several representations. The shared mental model is a stimulus for the mental model of the other team member. This stimulus can evoke different knowledge in each team member's mind. In the process of mental model transfer, all mental models and externalized mental models (representations) interact with each other to create a new common mental model. In this process, reasoning and transformation of knowledge can lead to creative results. Furthermore, mental models that are externalized as representations in this process do not always have to be visual. A word, a voice is also an external representation. Thus, these representations can interact with the mental model and they create a new result.

CHAPTER 3

METHODOLOGY

The research carried out in this thesis is of qualitative nature, using qualitative data collection strategies to examine an elongated design learning process focusing on interactive cognitive practices within the design studio environment.

The qualitative research method has many definitions in the literature. Denzin and Lincoln (1998) describe the general definition of qualitative research as follow:

> Qualitative research is multi-method in focus, involving an interpretive, naturalistic approach to its subject matter. This means that qualitative researchers study things in their natural settings, attempting to make sense of, or interpret phenomena in terms of the meanings people bring to them. Qualitative research involves the studied use and collection of a variety of empirical materials. (p. 8)

According to LeCompte and Goetz (1984), in qualitative research, three types of data are collected. These are environmental, perceptual, and process related data.

- Environmental data relates to the social, psychological, cultural, demographic and physical characteristics of the subject matter of the study. This type of knowledge is based on process and perceptual knowledge and it allows comparison with other environments.
- Process-related data relates to what is going on during the research and how those affected the research group.
- Data on perceptions reveals what the studied group thinks about the process.

There are five general strategies of inquiry in the qualitative study. These are ethnographies (Creswell 1998), grounded theory (Strauss and Corbin 1990), case studies (Stake 1995), phenomenological research (Nieswiadomy 1993), and narrative (Clandinin and Connelly 2000). There are various methods of collecting data for qualitative researches among which three are most commonly used in qualitative research: interviewing, observation, and review of written documents (LeCompte and Goetz 1984).

In this thesis, case study was used as a strategy of inquiry. The purpose of this study is to describe and explore a real-world example of design learning in the design studio by interpreting the cognitive activities that occur in the design learning process. The data for the case study was collected through semi-structured interviews and primary documents from different phases of design learning.

3.1. Case Study

The case study method has many definitions in the literature. Merriam (1998) defines qualitative case studies as a holistic research defining and analyzing of a case, a phenomenon, or a social unit. According to Yin (2002) case study is a research method that works within a real life environment.

The purpose of this case study is to present a concrete example to explore the research question which is "How does interactive imagery facilitate construction of shared mental models in a design learning environment?" This study is an inquiry on the effect of interactive imagery and shared mental models on the learning process in the one- to-one desk critiques of the studio. In this research, it was aimed to interpret the cognitive activities that occur during the design process in reference to the related literature. There are four different cases (Case 1, Case 2, Case 3, and Case 4) in this study. These cases examine the design learning process in the studio environment of four different architectural students.

The study is based on retrospective accounts of students and instructors. How design thinking occurs during the design process cannot be known directly by other people. In studies on this subject, there are three different methods to examine this activity. These are introspective method, retrospective method, and concurrent verbalization method (Ericsson 1998). In the introspective method, the accuracy and validity of the reports are interrogated. It is not certain that the subjects have valid information about the cognitive processes that shape their behavior. According to Ericsson (1998), the structure of self-emerging thoughts cannot be reported directly without any modifications because the process of expressing the thought might ramifications in the way we think. Thus, how one thought affects the other cannot be observed. However, relations between consecutive thoughts can be interpreted by retrospective analysis. In this respect, the retrospective method allows to obtain more

reliable and verifiable data. On the other hand, concurrent verbalization as a method allows the closest link between thought and reports (Ericsson 1998). However, the accuracy and validity of the method are interrogated because in the process, thoughts emerging through attention (subsequent thought) may not always be verbal. In addition to this, in concurrent verbalization method, in verbalization of thoughts, discourse of subject may be failure (Ericsson 1998).

In this thesis, data gathering began at the end of the project development. The cases were investigated after the phenomenon. Thus, the researcher was removed from the daily interactions in the studio to allow a distance from the subject matter of the study.

During the research process, semi-structured interviews were used to collect students' and instructors' accounts of the design process for each studied student. In these interviews, open-ended questions were used to ensure that the accounts would provide rich and detailed data. In the interviews, visual and verbal documents related to students' projects produced by students and instructors during panel and desk critiques were collected. The collected data and documents were analyzed and interpreted in the light of literature studies.

3.1.1. Participants

The students selected for this study are third-year students in the architecture department at Izmir Institute of Technology. Nine students in the studio were interviewed. However, four of them were examined in this study. The reason for this the participants were selected based on some criteria. These criteria were originality in design, accessibility of students, availability of data, and volunteering. Based on these criteria, the project and critical processes of four students, one of which was female and the others were male, were examined. All the instructors of the studio were also participants in the study. There were four instructors in the studio. Two of them were the main instructors and the other two were teaching assistants. During the research period, interviews were held with instructors as a part of the design process in the studio.

Students were expected to design a "center for collaborative practice" on a site, in Bayraklı, İzmir, determined by the instructors at the beginning of the 2017-2018 Fall semester. The semester continued for fourteen weeks. In the first four weeks, site analysis and case study was made and also students were expected to create a program. In fourth week, the panel review was made to present scenarios. Two midterm juries were made during the semester. The first of these juries was made in the seventh week and the second was done in the eleventh week. In the fourteenth week, the final jury was done and the semester was completed. In the studio, each student was required to develop a project in the light of a self-formulated concept. The critiques (one- to-one desk critiques, midterm jury, and panel review critiques) in the studio were conducted on rotational basis with each student getting feedback from a different instructor at every studio day. In this system, the student interacts with different instructors during the project development phase.

3.1.2. Procedure

During the study period, a semi-structured interview was conducted with students and instructors. Open-ended questions were used in these interviews. Interviewees were allowed to introduce any topic they might have thought relevant to the discussions which led to further emerging questions in the form of informal interviews.

In semi-structured interviews with students, the following questions were asked: How did you start this project? What was your starting point? How did you develop your project? With these questions, students' perceptions of their thoughts processes and their ideas were collected. The purpose in asking these questions was to collect data from which cognitive processes involved in the design learning process of each student. The students answered these questions both verbally and visually. Visual documents were various representations produced starting with the initial stage to the final stage. These representations were sketches, plan, section, and elevation drawings, diagrams, graphics, 3D digital models, physical models, 3D renders among others. These representations and retrospective verbal accounts provided data to trace the design process of students.

Some parts of the interviews included spontaneous questions in the form of informal interviews. In these questions, it was aimed to collect information about each student's project in detail. As each student had different processes, open-ended questions were used spontaneously in this part of the interviews. In questions that inquired the development, it was explored why and how students had changed or developed their projects. In addition, the influence of the verbal and visual material from instructors' critiques was also examined. The duration of interviews ranged from 45 to 60 minutes. The interviews were recorded. In addition, visual data provided by the students were either photocopied or photographed.

In semi-structured interviews with instructors, open-ended questions were used. These questions were: How did the student's project progress? How did the student develop the project? Every instructor explained the design process of the students through answering these questions. The visual documents collected from the students were shown to instructors to get their ideas about each of the documents and student's design process. The aim was to investigate how these visual documents were interpreted during desk critiques. Some parts of the interviews included spontaneous questions in the form of informal interviews. The duration of interviews ranged from 60 to 120 minutes. The interviews were recorded by phone.

After verbal and visual data were collected from students and instructors, a process was formed for each student by matching the verbal and visual data. The formed process was divided into steps according to the students' conceptual development stages. In this study, coding was not done while forming the process and matching data. All processes and steps were formed by interpreting the data obtained from the interviews.

3.2.3. Materials

The digital materials of the students were copied during the interview on a USB memory. Non-digital visuals were documented by photography. All recorded voice recordings, digital images and photos were transferred to a computer. The voice recordings were listened afterwards and these voice recordings were matched with visual material. As a result of this matching, each student's project process was divided into different phases.

3.2.4. Interpretations

In the research, steps of each student were interpreted on the basis of knowledge from the design studies literature. In interpretations, the relationship between design learning and interactive imagery facilitated through shared mental models were examined. The learning style of each student was discussed and analyzed. Lateral and vertical transformations of representations were examined. In addition to this, the reasoning styles that occurred in the process were identified.

CHAPTER 4

CASE STUDIES

Four students' project developments were investigated in this study. These were analyzed specifically with a focus on the conceptual phase. The project development continued for fourteen weeks and in some cases the conceptual phase continued till after the tenth week when the third midterm of the semester was scheduled. In each case study, the relationship between design learning and interactive imagery facilitated through shared mental models are examined. The learning style of each student is discussed and analyzed in the context of Goldschmidt's research (2005). These learning styles are conceptual learning and professional learning. Lateral and vertical transformations in the students' representations were examined based on knowledge from Goel's study (1995). In addition to this, episodes of "seeing as" and "seeing that", as defined in the work of Goldschmidt (1991), are identified in each design process.

4.1. Case 1 – Student 1

Student 1 adopted an "explorer" attitude in his project process. He changed his initial concept during the project development process. He tried to adapt new ideas to the project by taking into consideration the ideas and suggestions of the instructors. Student 1 was eager to develop and change his project.

4.1.1. Process

In the beginning of the process, the student presented his first proposal at the first panel review of the semester during the fourth week. The proposal of the student was developed based on his observation that individual buildings built recently in the area are disconnected from each other. Instead, he proposed that it will be better to "create connection between the high buildings". In the interview, student explained his idea as follow:

> There are a lot of high buildings around the project site. However, there is no connection among these buildings. Each one has a life in itself but there is no relationship with the environment. For this reason, people are running away from this area in their daily lives. Also, they do not prefer to come to this area if they do not have jobs or errands to run. I think people feel lost between high buildings. I noticed these problems. For this reason, I proposed different ideas to attract people to this area in the project. For example, job opportunities, street integrity etc…

Student presented these ideas at the panel review (Figure 3). He used different representations to explain his ideas. These were collage, diagram, 3D model and model. The instructors mentioned an example, which they thought could be beneficial to the development of the idea (Figure 4). In the interview, student explained instructors' comments as follows:

> Instructors said that my initial scheme did not reflect my concept. They stated that the model does not have the same affect with the collage and the buildings in the model are not high. In addition to this, instructors did not like my scheme. For this reason, I gave up this idea.

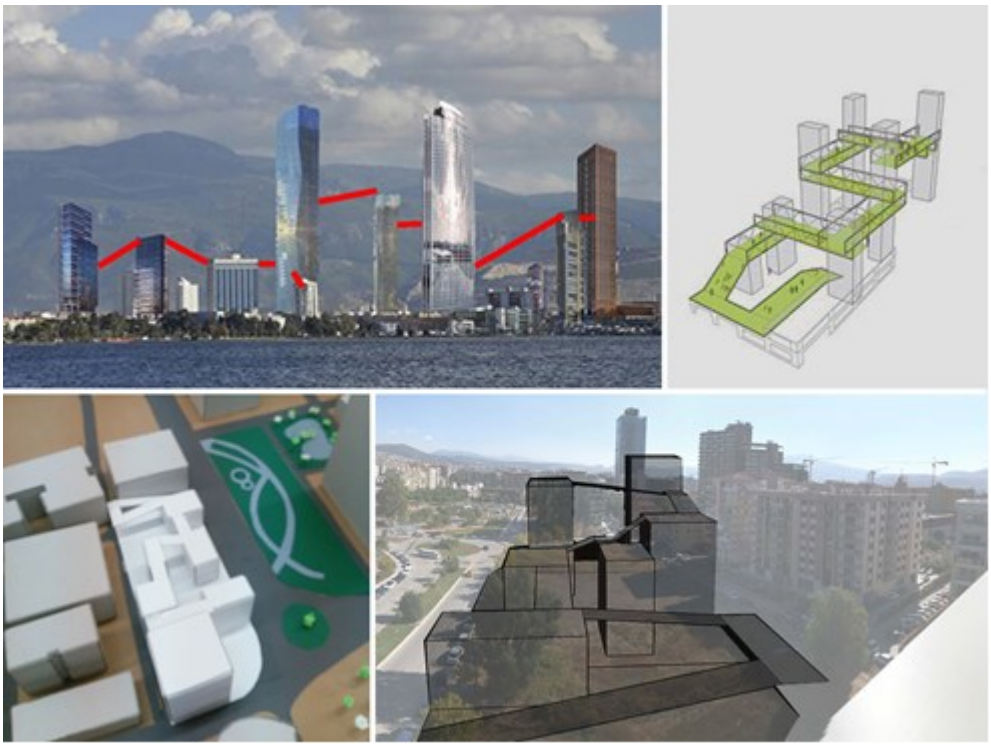


Figure 3: Representations of Student 1

In the interviews I made with instructors about the panel review, Instructor 2 and Instructor 4 stated that they do not remember exactly what they said, while Instructor 1 explained his opinion of student's scheme in the panel review as follows:

> I told him that the connectors used in the project were weak. Also, I gave an example. This example was Cophenhagen Gate by Steven Holl.

In the interview, Instructor 3 explained his view of the project as follows:

> In the panel review, student's concept and student's representations did not match each other. The student wanted to connect the buildings with each other and he wanted to create street integrity. However, in his representation, he used only simple surfaces as connectors. I think this was insufficient, only surfaces are used as connectors. I mentioned that the surfaces should not be like skate parks. Also, I mentioned that the connectors should become spaces.

Figure 4: Cophenhagen Gate by Steven Holl
(Source: Steven Holl website, 2018)

The student decided to change his project after the panel review. In the interview, student explained his decision as follows:

> After the panel, I started to work on my concept. I tossed away everything I did before. Then I made a model and 3D digital model and I developed a concept through them. My concept was "work-game". My goal was to create a space where work and game were together. I found this concept more suitable because a space is created for both work and game. I wanted to create a work space by creating another world within a world. I thought that I can do another world with the game.

Student presented his second proposal (Figure 5) at the first desk critique with Instructor 1. Instructor 1 made a sketch and he gave the example of *Rolex Centre* by Sanaa (Figure 6). Instructor 1 explained his idea at the desk critique as follows:

> The student presented a new concept. This concept was "work and game". Based on student's concept and images I reinterpreted his idea as "fluidity between work and game". I mentioned that fluidity should be between spaces and program items. Also, I gave an example, Rolex Centre, as a precedent.

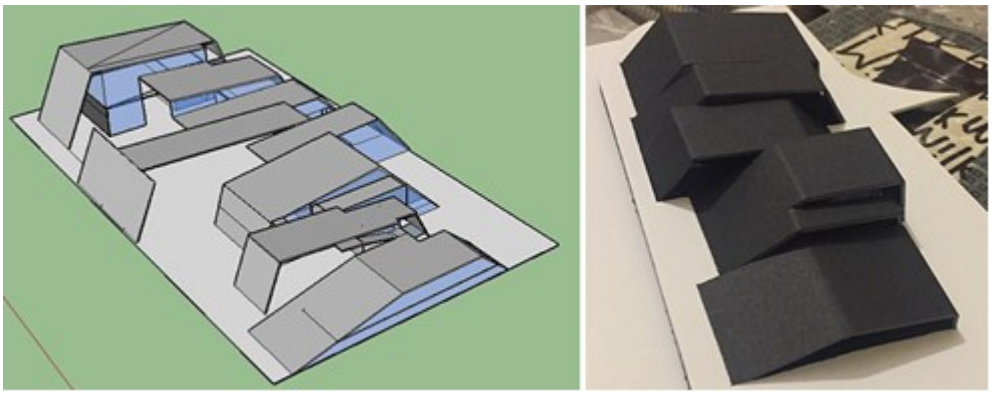


Figure 5: Digital model and model of Student 1

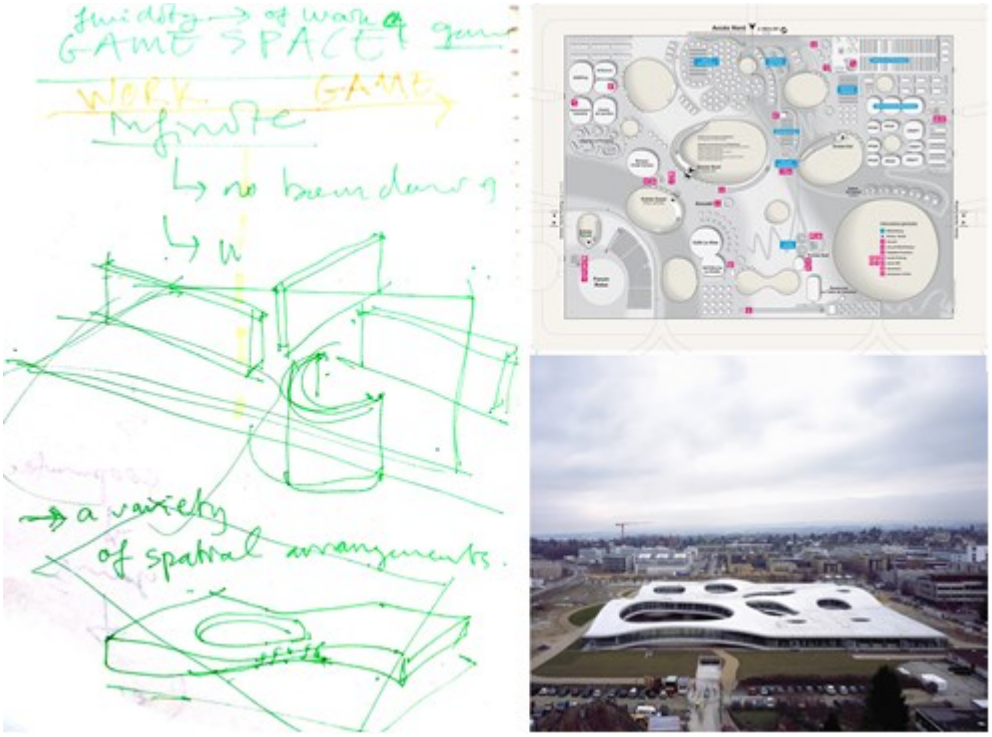


Figure 6: Sketch of Instructor 1 and Rolex Centre by Sanaa
(Source: Mimdap website, 2018)

The student drew sections after the desk critique (Figure 7) to work on this new scheme and on Instructor 1's feedback. At the midterm jury, student presented his idea and project development with different type of representations. These representations were conceptual diagram, 3D digital model, model, and section (Figure 8). During the midterm jury, instructors commented on his proposal also they gave an example *Zamet Sport Center* by 3LHD Architects as a precedent (Figure 9). Student explained instructors' comments at the midterm jury as follows:

At the midterm jury, instructors found that the project was insufficient in terms of light. I drew a section to show the light condition but it did not work. Then, they gave me an example Zamet Sport Centre by 3LHD Architects as a precedent. They said this example could be an example of how to bring in light. They also said that the project's location was wrong on the site.

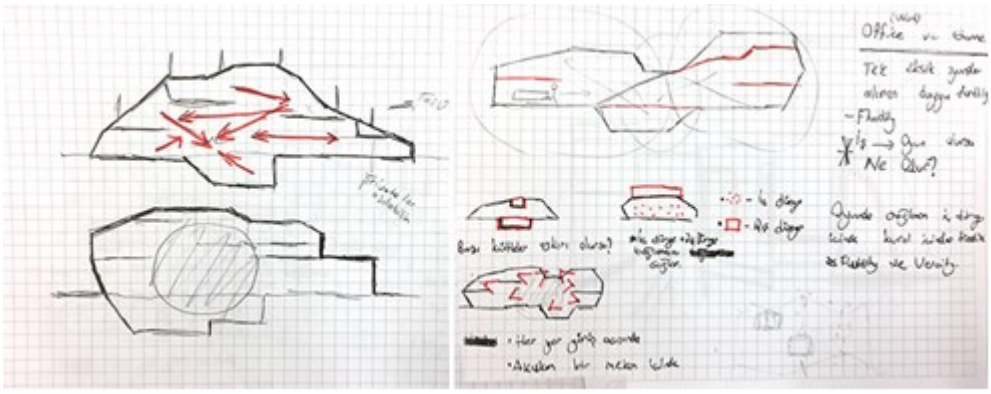


Figure 7: Sketches of Student 1

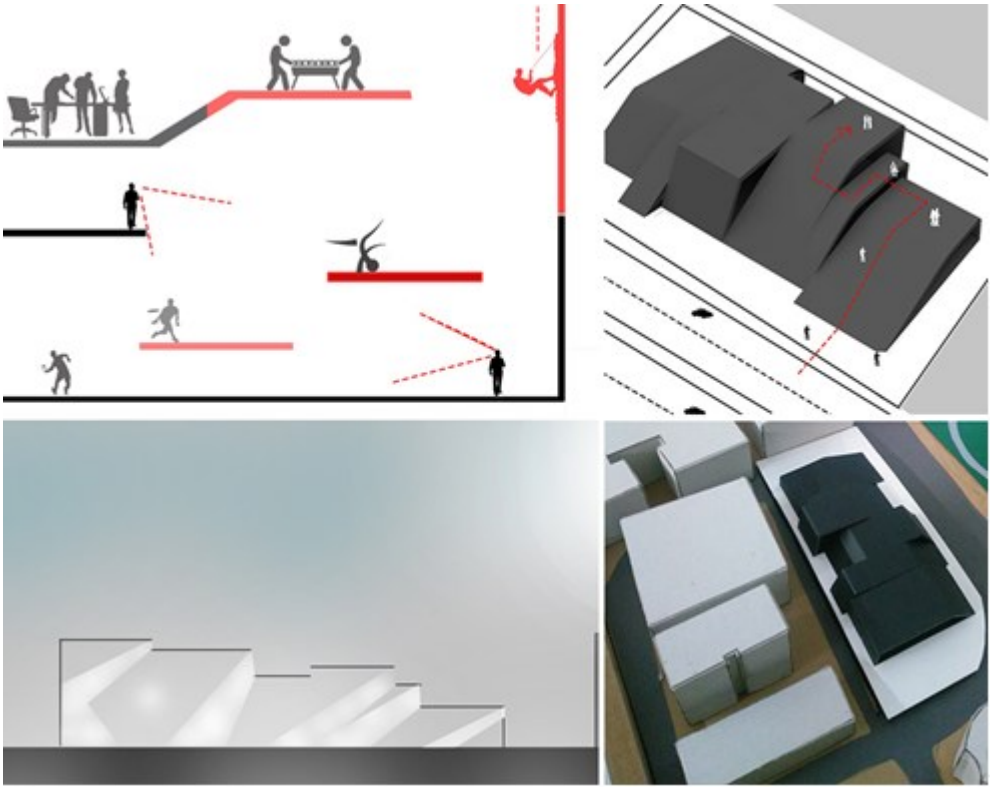


Figure 8: Midterm jury representations of Student 1

Instructor 2 explained his comments at the midterm jury as follows:

I told him that the shell is just creating an introverted world. The thickness of the bands was insufficient to house adequate spatial combinations. The possibility of dark spaces was very

> high. Site was 6000 m². The mass was only getting light from two sides because student put the bands side-by-side. Thereby, I told him that you could solve the problem of light by making these bands thinner and/or longer and by changing the alignment. Also I said that you could solve the light problem by creating holes in the shell. I mentioned him that the mass is in the wrong orientation to get natural light. Also, I said that with these changes, the project could gain different spatial diversity and it could create the spatial richness required by the concept. I suggested creating different spaces in outdoor through back and forth movement of the shell. Also, I gave an example Zamet Sport Centre by 3LHD Architects as a precedent at the midterm jury. I emphasized the significance of this example, the shell should not be considered as just a cover. I mean, work was under the shell and game was on the shell, which sounded wrong to me. Shell should be considered not only as 2D component but also as 3D feature. For this reason, I said that there needs to be spaces between the interior and exterior space. The shell had to be spatialized. In my opinion, if he did these changes, he could reflect his concept adequately.

Instructor 3 explained his comments at the midterm jury as follows:

> I questioned what is relevant between the form and his concept. I said that I think the "work and game" concept is symbolic. Also, I indicated that the form should reflect the concept.

Figure 9: Zamet Sport Center by 3LHD Architects
(Source: ArchDaily website, 2018)

After the midterm jury, the student designed a new scheme in a new 3D digital model (Figure 10). Student explained his model as follows:

> After the comments from the midterm jury, I focused on the light problem. I wanted to try turning the project alongside the main road. However, I did not like the model which I made.

Student presented the new 3D digital model at the following desk critique with Instructor 4. Instructor 4 gave *the Administrative Building of Organization of Islam Conference* by Alper Ünlü (Figure 11) as an example. Instructor 4 explained that:

I said that the project with the new form lost the spatial potentials that the old form could provide. I mentioned that he could solve the light problem with the old form. I said that you could solve the problem by moving the bands back and forth and by changing the heights of bands. Also, I gave an example, namely Administrative Building of Organization of Islam Conference by Alper Ünlü as a precedent. I think this example was similar to the student's project in terms of "form" and "solution to the light problem". I think it was a good example.

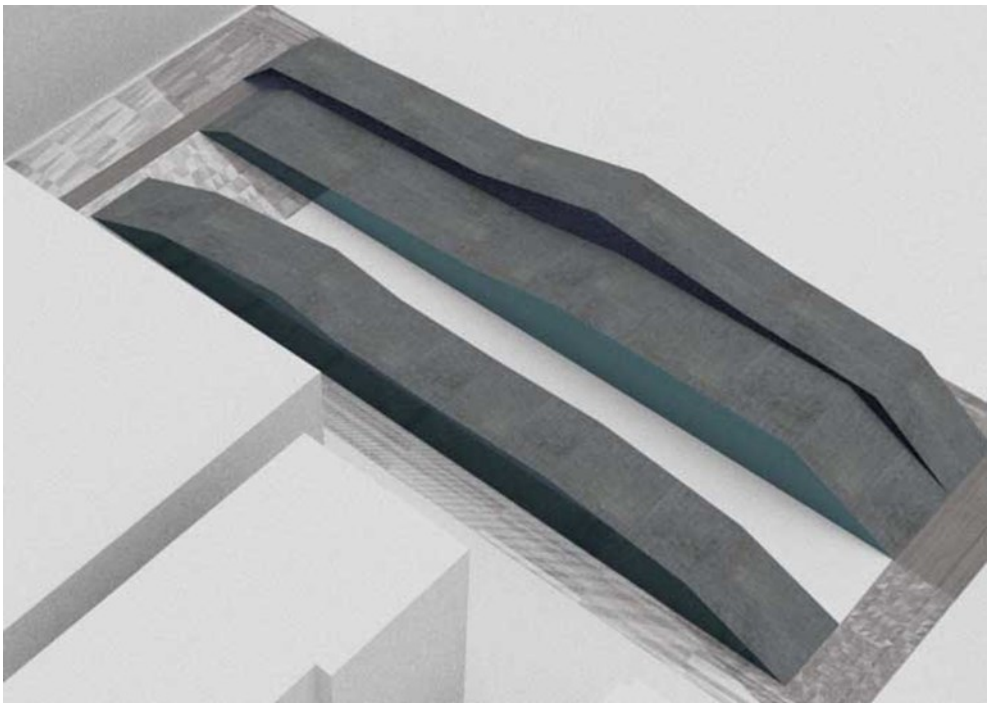


Figure 10: Digital model of Student 1

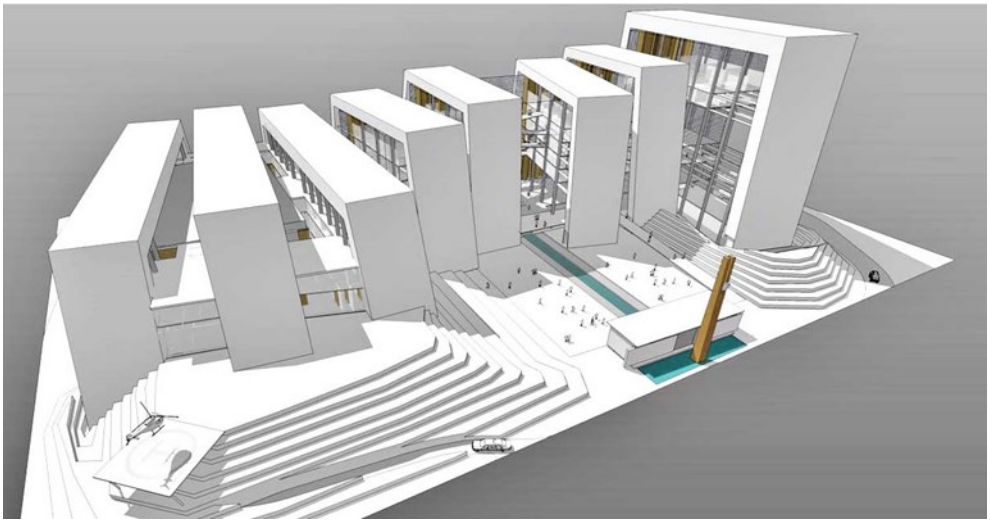


Figure 11: The Administrative Building of Organization of Islam Conference by Alper Ünlü (Source: Arkitera website, 2018)

The student returned to the previous form after the desk critique and he continued to develop his project. He designed a new model (Figure 12). He explained his model as follows:

> I returned to the old form after the desk critique. As mentioned in the critique, I moved the bands back and forth. Also, I tried to solve the light problem. In addition to this, I changed the height of the bands.

Student presented this model at the following desk critique with Instructor 1. Instructor made a sketch also he gave two example, *Vilhelmsro Primary School* by BIG and *Zhangjiang Future Park* by MVRDV (Figure 13). Instructor 1 explained the desk critique as follows:

> I reminded the student of the fluidity-in-space and fluidity-in-program that I mentioned at the very beginning of the process. I drew a sketch about it. In this sketch, I mentioned that the shell-space relation should be both about indoor and outdoor. I said that fluidity must be in all spaces. In addition to this, I suggested he could use the spaces that resulted from back and forth movement of the bands as inner gardens. Also, I suggested fluidity should be a guiding principle on top of the shell. I gave two examples about spatial fluidity and internal-external relations. One of them is Vilhelmsro Primary School by BIG, another is Zhangjiang Future Park by MVRDV.

After the desk critique, student continued to develop his project. He drew a plan, sections, and elevation also, he made 3D digital model (Figure 14). Thereby, he completed the conceptual development process of his project. Student explained the conceptual development process of his project as follows:

> I did everything that instructors' suggested in critiques and juries. I solved the light problem. By moving the shell back and forth, I created different outdoor spaces and indoor spaces. I created inner gardens. I created ramps and stairs in between bands. I created fluidity for the top of the shell.

Instructor 1 explained the conceptual development process of student's project as follows:

> I think he did not fully understand what fluidity was about. There was no fluidity between spaces and between inside and outside. He could not achieve fluidity.

Instructor 2 stated the following:

> I think he could not solve the light problem enough. He tried to solve this problem through back and forth movement of bands but I think he could not solve it. Also, I think it was not a suitable mass for the work office spaces. In addition to these, he could not realise shell as a structure.

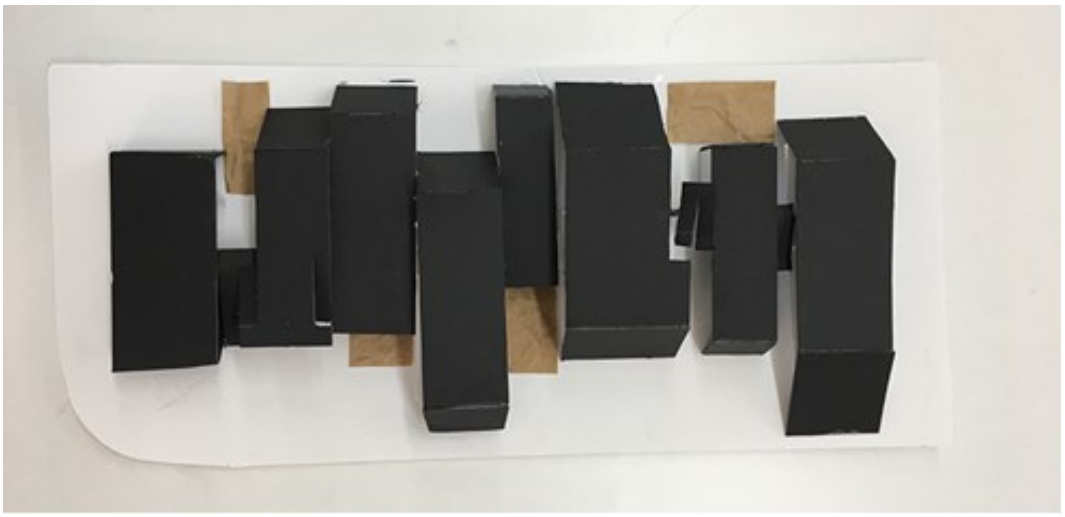


Figure 12: Model of Student 1

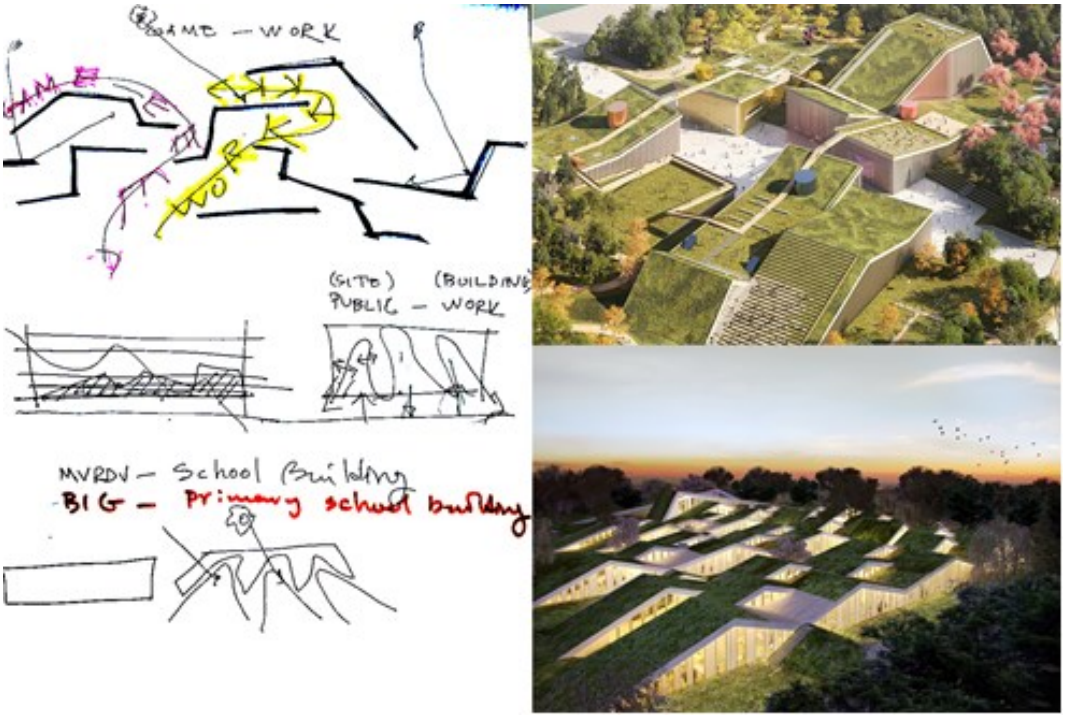


Figure 13: Sketch of Instructor 1, Zhangjiang Future Park and Vilhelmsro Primary School (Source: ArchDaily website, 2018)

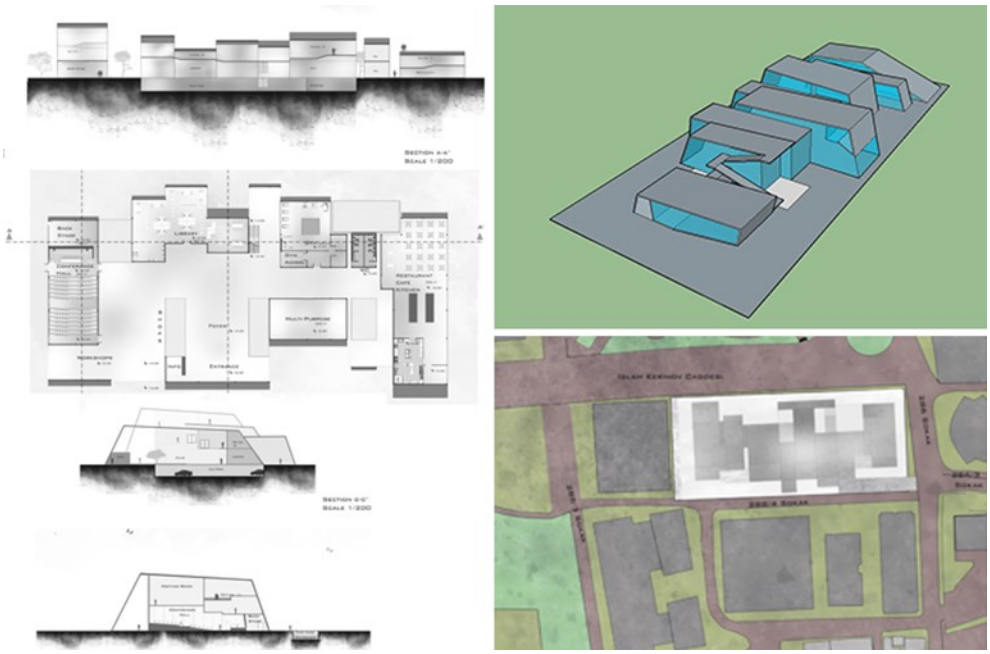


Figure 14: Representations of Student 1

Instructor 3 explained it as follow:

> Student could not reflect on the relations between work and game in his project. I think this relation remained symbolic.

Instructor 4 added:

> I think this project was superficial. The student could not understand the requirements of the project and the concept.

4.1.2. Interpretation

In this section, the conceptual development process of the student's project is examined in five steps. These steps were Step 1 - Panel Review, Step 2 – Desk Critique with Instructor 1, Step 3 – Midterm Jury, Step 4 – Desk Critique with Instructor 4, and Step 5 – Desk Critique with Instructor 1.

Step 1 – Panel Review

The idea of the student was to "create integrity among isolated buildings" which morphed into a work/game space after the first panel review. The process of the student

is summarized graphically (Figure 15) and the types of reasoning and transformations are tabulated (Table 1) as follows:

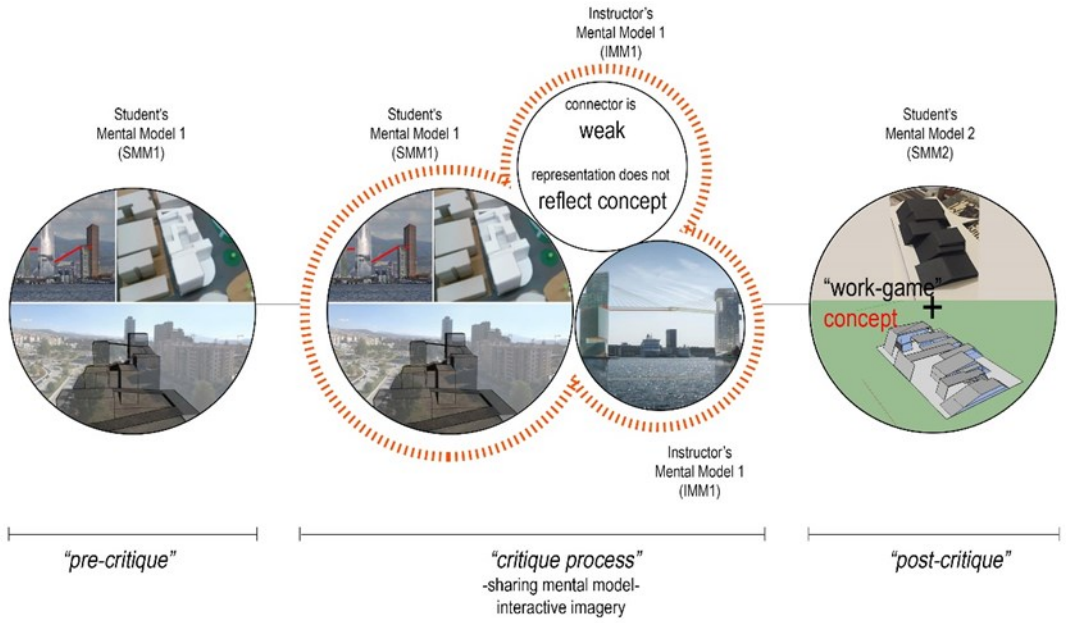


Figure 15: Step 1 of Case 1

Table 1: Step 1 of Case 1

Step1	**Type of Reasoning**	**Type of Transformation**
Student	seeing as	lateral transformation
Instructor 1	seeing as	lateral transformation
Instructor 3	seeing as	x

At the panel review, instructors argued that the representations did not reflect the idea because they thought that connectors among buildings were weak. They mentioned that components should become spaces. Instructors' reasoning type can be interpreted as "seeing as" at this step because they interrogated the relationship between the concept and the form interpreted the "connector" as a stronger spatial feature rather than just a two dimensional bridge connection. The difference between the representation of instructors and the representation of the student implies a "lateral transformation" since the connector is suggested to become more than a bridge. The components that connect the buildings in the student's scheme were only planar elements. However, the connecting components that instructors mentioned as suggestions and examples were spatial components.

After the panel review, there was a big rupture and the student abandoned the initial concept. Student developed a new concept and a new form. The type of reasoning of the student in this process can be interpreted as “seeing as”. The reason is that student used planar elements to create connection in his first proposal but he used a shell form to create connections in second proposal. In other words, the student designed a shell after the spatial proposals of the instructors or he converted the connecting bridges into a series of shells. On the other hand, the change between the first proposal and the second can be interpreted as a “lateral transformation”. The reason is that there was a conceptual and formal difference between the first proposal and the second proposal. The student represented the idea of connection with a shell proposal instead of simple surfaces.

At this stage, the student used instructors’ comments in his second proposal by way of changing his conceptual approach to the design problem. For this reason, “conceptual learning” occurred in this process of student.

Step 2 – Desk Critique

The student made a conceptual shift after the first panel review and converted the two-dimensional bands of bridges into a series of shells and introduced a new conceptual approach by way of thinking of work as a continuation of and in unity with game. His goal was to create a space where work and game could happen together. At the critique, the instructor gave student a clue about the conceptual knowledge of how to convert his conceptual idea into a spatial scheme by way of introducing the notion of fluidity in space and among program activities. After the desk critique, student continued his project. He drew sections (Figure 7). The process of the Step 2 (Figure 16) is summarized (Table 2) as follows:

At this stage, instructor’s reasoning type can be interpreted as “seeing as” since the notion of fluidity is introduced on top of the coexistence of work and game. In other words, instructor assessed the project from a spatial and programmatic perspective. Instructor’s example and sketch were about spatial organization. On the other hand, the shift from student’s representation to Instructor 1’s representation can be interpreted as a “lateral transformation”. The reason for this is that the proposals and examples are conceptually different from the representation of the student. In student’s

representation, concept was considered as a form. However, instructor considered concept as a spatial organization.

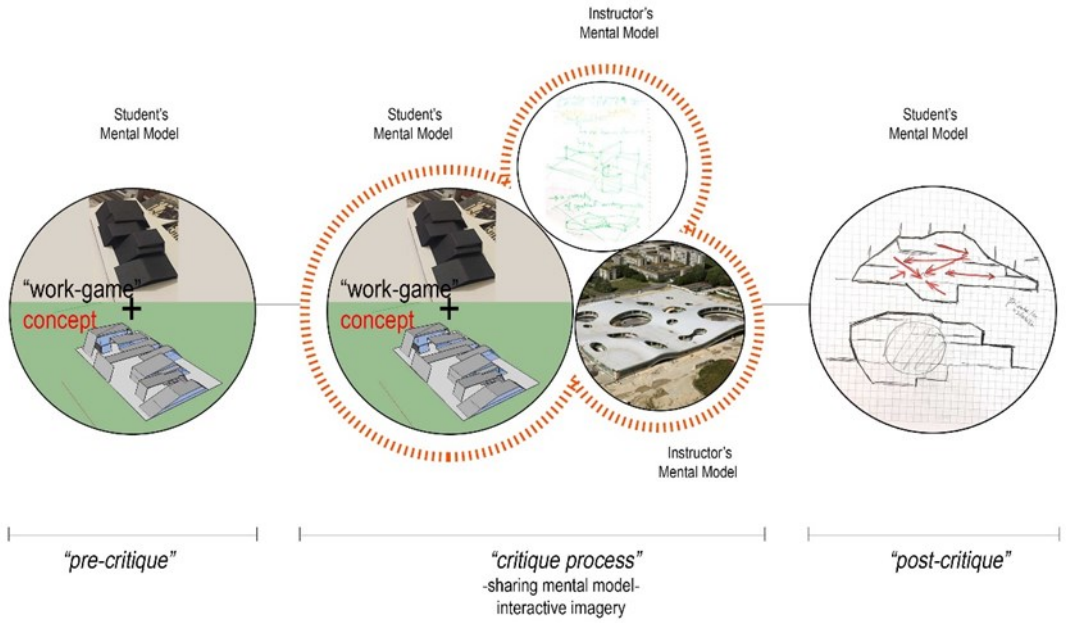


Figure 16: Step 2 of Case 1

Table 2: Step 2 of Case 1

Step 2	**Type of Reasoning**	**Type of Transformation**
Student	seeing as	lateral transformation
Instructor 1	seeing as	lateral transformation

While Instructor 1 suggested a spatial concept, he presented his idea through a perspective plan. The student tried out this idea by drawing sections. At this point, instructor's reasoning type can be interpreted as "seeing as". On the other hand, the change between the pre-critique representation of student and post-critique representation of the student can be interpreted as a "lateral transformation". The reason is that student tried to reflect the concept only in form in pre-critique. However, he tried to reflect the concept in the spatial organization during post-critique.

Instructor's example and sketch were a conceptual approach to the student's project. Instructor 1 presented the knowledge that will affect the conceptual development of the project. The student developed a new conceptual approach using

this knowledge. For this reason, it is possible to interpret the learning style of the student at this step as “conceptual learning”.

Step 3 – Midterm Jury

The student continued the conceptual development process of the project after the desk critique and designed a new scheme (Figure 8). In response, the instructors highlighted issues such as “elimination of the light problem”, “examination of the building orientation on the site”, “rethinking of bands’ thickness”, and “providing indoor-outdoor fluidity”. The process of Step 3 is summarized in Figure 17 and Table 3.

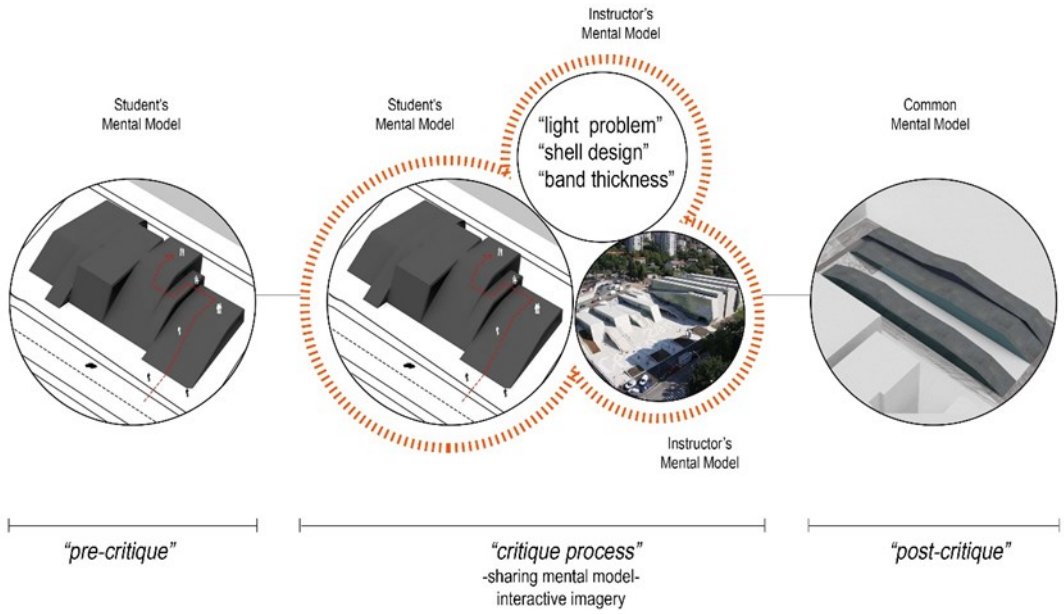


Figure 17: Step 3 of Case 1

Table 3: Step 3 of Case 1

Step 3	**Type of Reasoning**	**Type of Transformation**
Student	seeing that	vertical transformation
Instructor 2	seeing as	lateral transformation
Instructor 3	seeing as	x

Instructor 2 reported that the bands’ thicknesses were too wide at this stage and emphasized that the interior may have a light problem. At this point, instructor’s reasoning type can be interpreted as “seeing as” because he talked about the differences that may arise in the interior because of the changes in the external form. In addition to these, Instructor 3 interpreted the student's representation from a different point of view.

He questioned the relationship between form and concept. He stated that the "work-game" concept was not reflected in the form and it was symbolic. Therefore, this reasoning type can be interpreted “seeing as” also. The student did not have any signs that he thought about indoor-outdoor fluidity in his proposal, which was suggested by the instructors at the midterm jury. In other words, they presented a new conceptual approach. Therefore, it can be said that this was a “lateral transformation” between the proposals.

The student rotated the mass on the site to alleviate the light problem and used different a different formal approach on the site. At this point, student’s reasoning type can be interpreted as “seeing that”. On the other hand, in the post-critique proposal, student rotated the mass 90 degree. He reduced the number of bands and their thickness. He left spaces between the bands instead of using attached bands. Student only changed the orientation of the project which does not suggest a new conceptual approach. For this reason, the student's representation change can be interpreted as a “vertical transformation”.

Instructors offered both procedural knowledge and conceptual knowledge at the midterm jury. Procedural knowledge was in relation to light and band thicknesses. Conceptual knowledge was in relation to spaces and fluidity. It is possible to say that the student used only procedural knowledge at this stage because there were no changes in the conceptual approach in the post-critique proposal. For this reason, it is possible to interpret the learning style of the student at this step as “professional learning”.

Step 4 – Desk Critique

After the midterm jury, student presented his renewed proposal (Figure 10) at the desk critique with Instructor 4. Instructor 4 stated that the old form had more potential. After the desk critique, student created a new model (Figure 12). This step (Figure 18) is summarized (Table 4) as follows:

Instructor 4’s reasoning type can be interpreted as “seeing as” because she made conceptual suggestions about the interior space. The instructor’s focus on the interior space suggests a shift. Therefore, the change between the representation of instructors and the representation of the student can be interpreted as a “lateral transformation”.

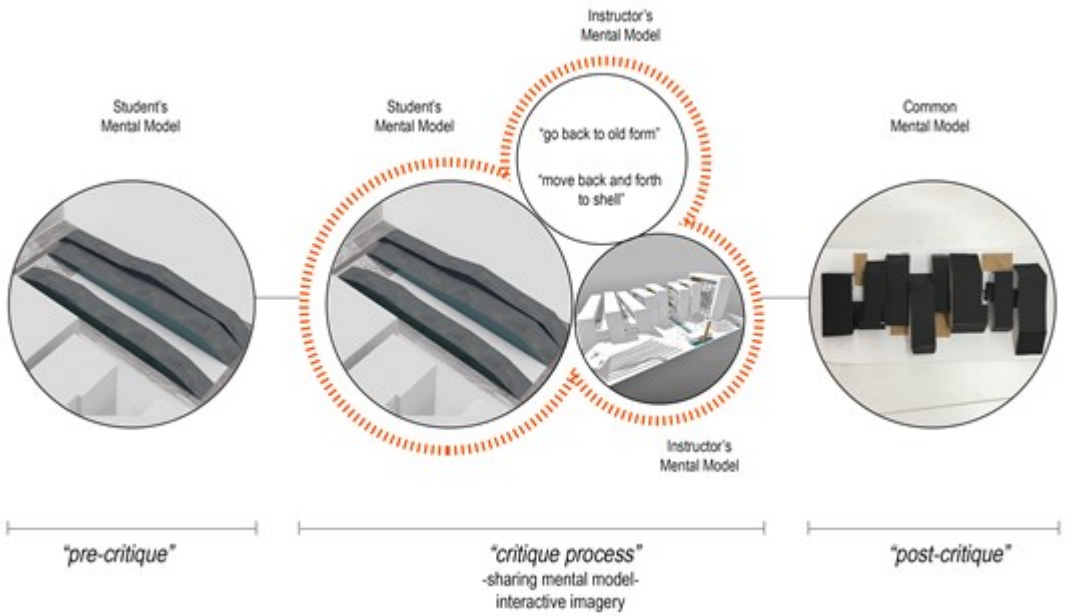


Figure 18: Step 4 of Case 1

Table 4: Step 4 of Case 1

Step 4	**Type of Reasoning**	**Type of Transformation**
Student	seeing as	lateral transformation
Instructor 4	seeing as	lateral transformation

The student afterwards returned to the previous massing and moved the bands back and forth to solve the light problem. Thus, he conceptually changed his project. For this reason, the type of reasoning of the student in this process can be interpreted as "seeing as". On the other hand, the change between the first scheme of student and later scheme can be interpreted as a "lateral transformation". The reason is that both interior and exterior have changed with the conceptual approach developed in response to the light problem.

Instructor 4 presented both procedural knowledge and conceptual knowledge at the desk critique. Procedural knowledge was in relation to the solution of the light problem. Conceptual knowledge was in relation to form and its advantages. It is possible to say that the student used both type of knowledge in the new proposal because the student moved bands back and forth to solve the light problem also he returned to the previous mass and made use of the spatial advantages of this form. Therefore, it is possible to interpret the learning style of the student at this step both "professional learning" and "conceptual learning".

Step 5 – Desk Critique

Student presented his new proposal (Figure 12) at the desk critique with Instructor 1. Instructor 1 reminded the fluidity in space and fluidity in program that he mentioned in his previous desk critique. The process of the student (Figure 19) is diagrammatically summarized (Table 5) as follows:

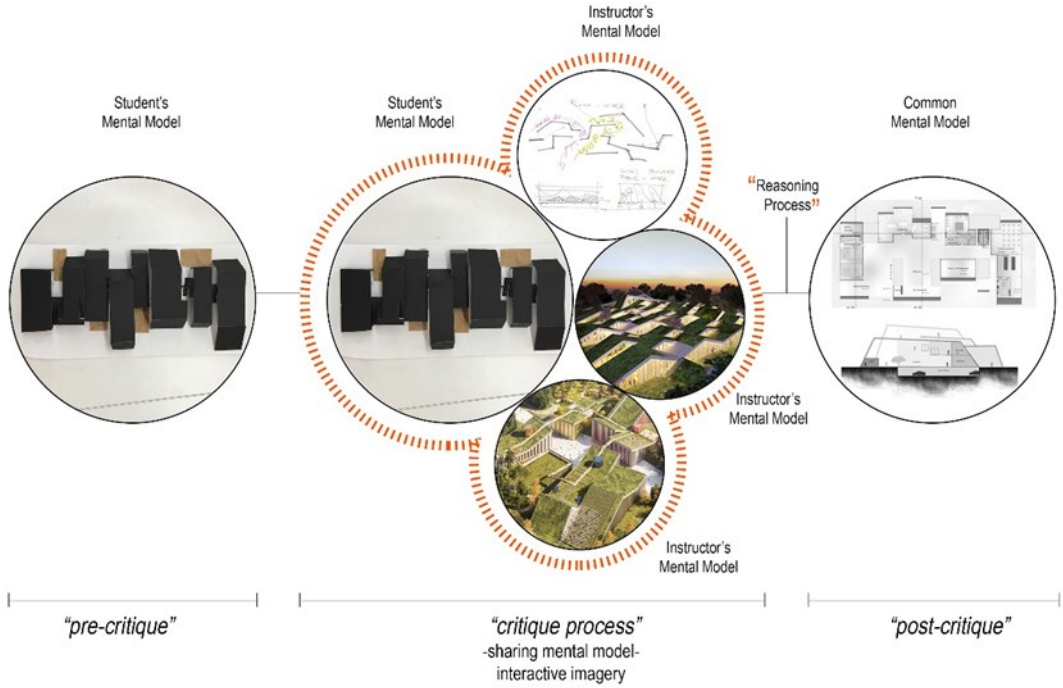


Figure 19: Step 5 of Case 1

Table 5: Step 5 of Case 1

Step 5	**Type of Reasoning**	**Type of Transformation**
Student	seeing as	lateral transformation
Instructor 1	seeing as	lateral transformation

Instructor 1 suggested conceptual ideas for both interior and exterior space. These suggestions were fluidity in space, fluidity in program, inner gardens, and establishing interior-exterior relationships. The instructor suggested ideas to solve the conceptual deficiencies observed in the current project. At this point, instructor's reasoning type can be interpreted as "seeing as". On the other hand, the change between the scheme of Instructor 1 and the scheme of the student can be interpreted as a "lateral

transformation". The reason for this is that the proposals and examples are conceptually different from the representation of the student.

The student tried to apply the conceptual ideas proposed by Instructor 1. He created inner gardens. He designed ramps and stairs in between bands and provided fluidity on the top of the shell. At this point, student's reasoning type can be interpreted as "seeing as". On the other hand, the changes made by the student caused spatial and conceptual changes. For this reason, the student's representation change can be interpreted as a "lateral transformation".

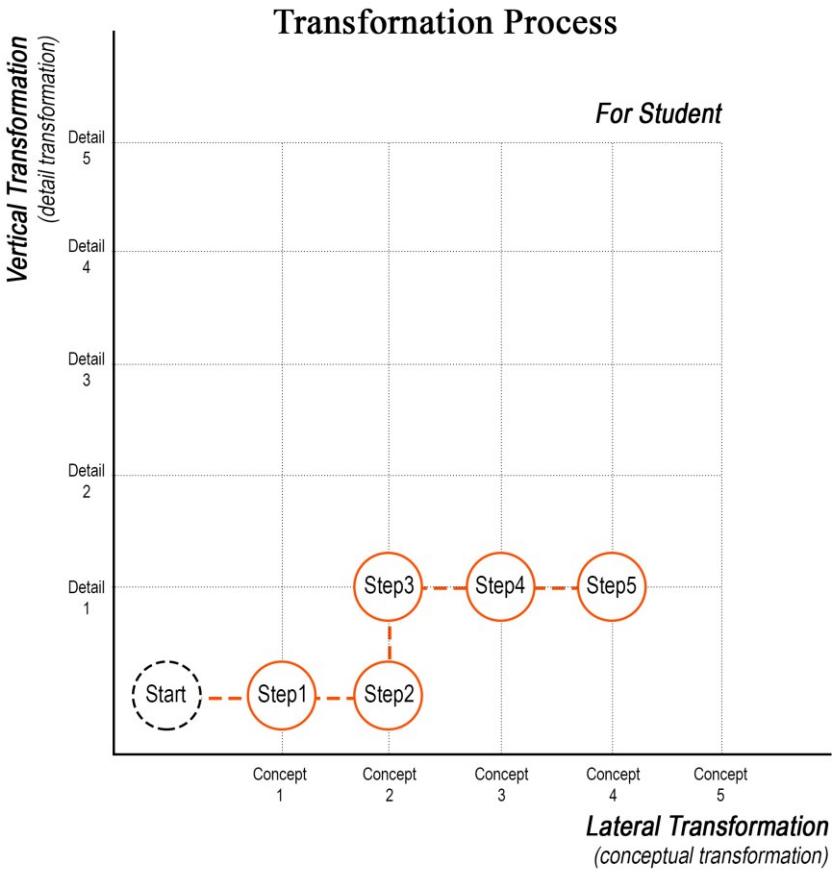
Instructor 1 presented conceptual knowledge at the desk critique which pointed the relevance of fluidity for the current design situation. It is possible to say that the student used some conceptual knowledge in this process. The reason is that he created inner gardens and he tried to provide fluidity for the top of the shell through ramps and stairs. However, he could not provide fluidity-in-space and fluidity-in-program throughout the project. Although the student did not use all the conceptual knowledge, it is possible to interpret the learning style of the student at this step "conceptual learning" because he used some of them.

4.1.3. Discussion

In this section Case 1 is discussed in terms of cognitive components of design, i.e., representation and reasoning.

Representation

In this case, the student achieved a final scheme mostly with lateral transformations (in Step 1, Step 2, Step 4, and Step 5) in the conceptual development process (Figure 20). In this point, it is possible to say that the student arrived at a final scheme with conceptual shifts from the knowledge which was obtained from critiques and juries. In terms of instructors, all of them used lateral transformation at all steps. It is possible to interpret that instructors offered a conceptual point of view for the student's project.



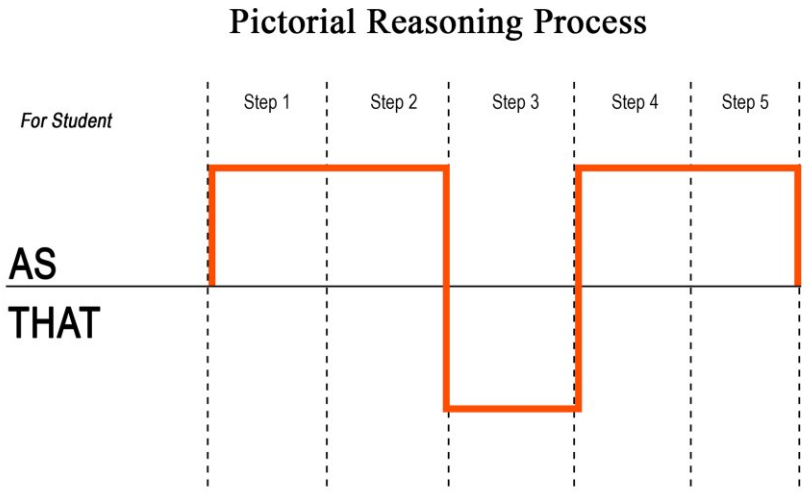


Figure 20: Transformation Process and Pictorial Reasoning Process of Case 1

Reasoning

In the conceptual phase of this student, pictorial reasoning is mostly "seeing as" (in Step 1, Step 2, Step 4, and Step 5) (Figure 20). It is possible to say that the student exegetically used the conceptual and procedural knowledge which is given by the

instructors. In terms of instructors, all of them used “seeing as” at almost all steps. It can be said that they proposed a new conceptual approach by recalling knowledge from their minds through the student's representation as a stimuli.

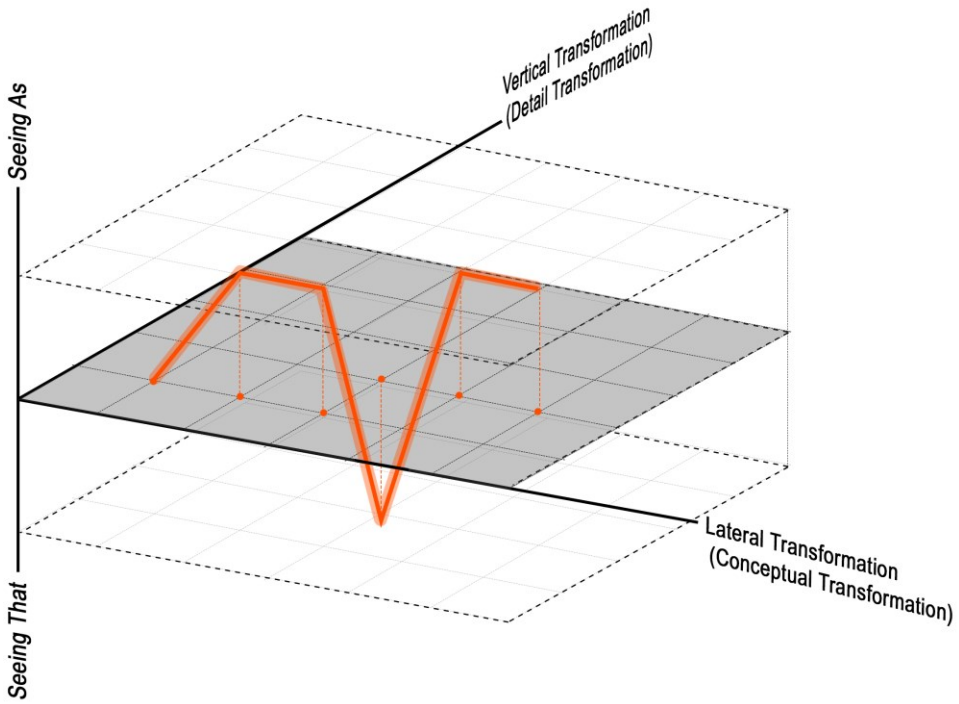


Figure 21: Design Path of Case 1

Briefly, in this case, the student began the project with the idea of “creating connections between high buildings” but continued with a different approach. This concept was “work-game”. During the conceptual development process of student’s project, he tried to reflect the concept requirements on his design scheme. His project was transformed mostly through “lateral transformation”. In other words, he mostly developed his project conceptually (Figure 21). It is possible to interpret that student took into consideration instructors’ proposals and he tried to use it.

4.2. Case 2 - Student 2

Student 2 adopted a "scrutinizer" attitude in his project process. He continued to develop his project with the initial concept. He avoided radical changes throughout the process. Student 2 did not consider instructors' suggestions too much in order not to change his project.

4.2.1. Process

Student 2 started his design scheme with a focus on “collaborative work”. The student associated this concept with an “ant colony”. He first presented his conceptual approach at the first panel presentation (Figure 22). The student explained his idea as follow:

> When I was thinking of workspace, I thought about ants. Ants live and work both underground and on the ground. I wanted to reflect this idea on the project. I created three different spaces for this. These are communal life, public life, and working life. Communal life is underground. Working life is on the ground. And public life is the boundary, which is ground. I presented these ideas with diagrams, a section drawing, and a 3D digital model at the panel review. Instructors praised my conceptual approach. They said that the project should be developed conceptually and spatially. Also, they indicated that the mass is very static.

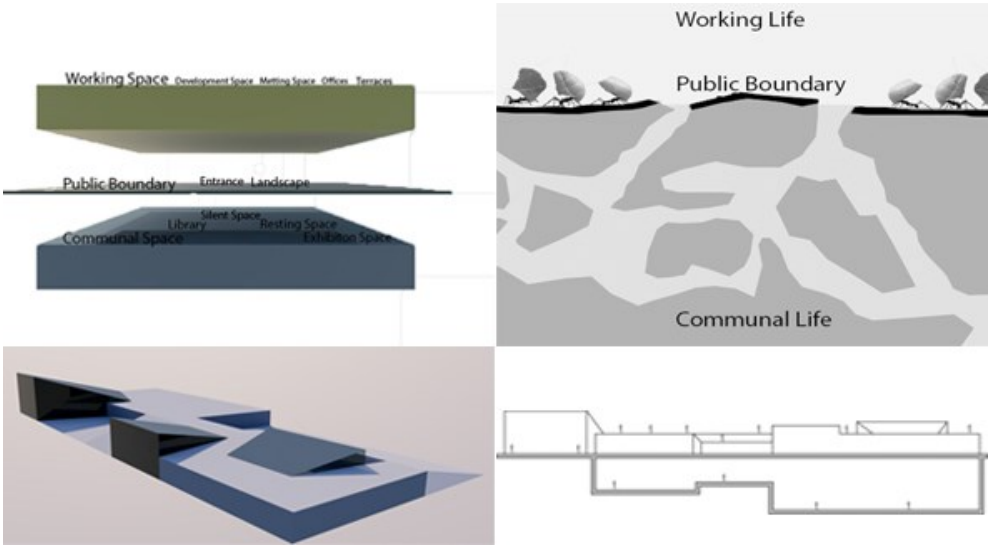


Figure 22: Representations of Student 2

Instructor 1 explained his idea at the panel review as follows:

> I think his concept was interesting. I liked the concept. However, he had not realized how the metaphor would lead the spatial design. I commented on this. I said that he should think about the concept and he should reflect it on the form and the spaces.

After the panel review, student did not add anything new and he brought the same material at the desk critique with Instructor 1. He explained his idea as follows:

> I could not think straight and I did not add any new things.

At the desk critique, Instructor 1 suggested some ideas and he made a sketch and a paper model to explain his ideas (Figure 23). The instructor explained his contribution as follows:

> I explained the ant metaphor and how the metaphor could be converted into a spatial organization. I suggested him to use the shell as a topography. Then, I made a sketch and a model to show the relationship between shell and topography.

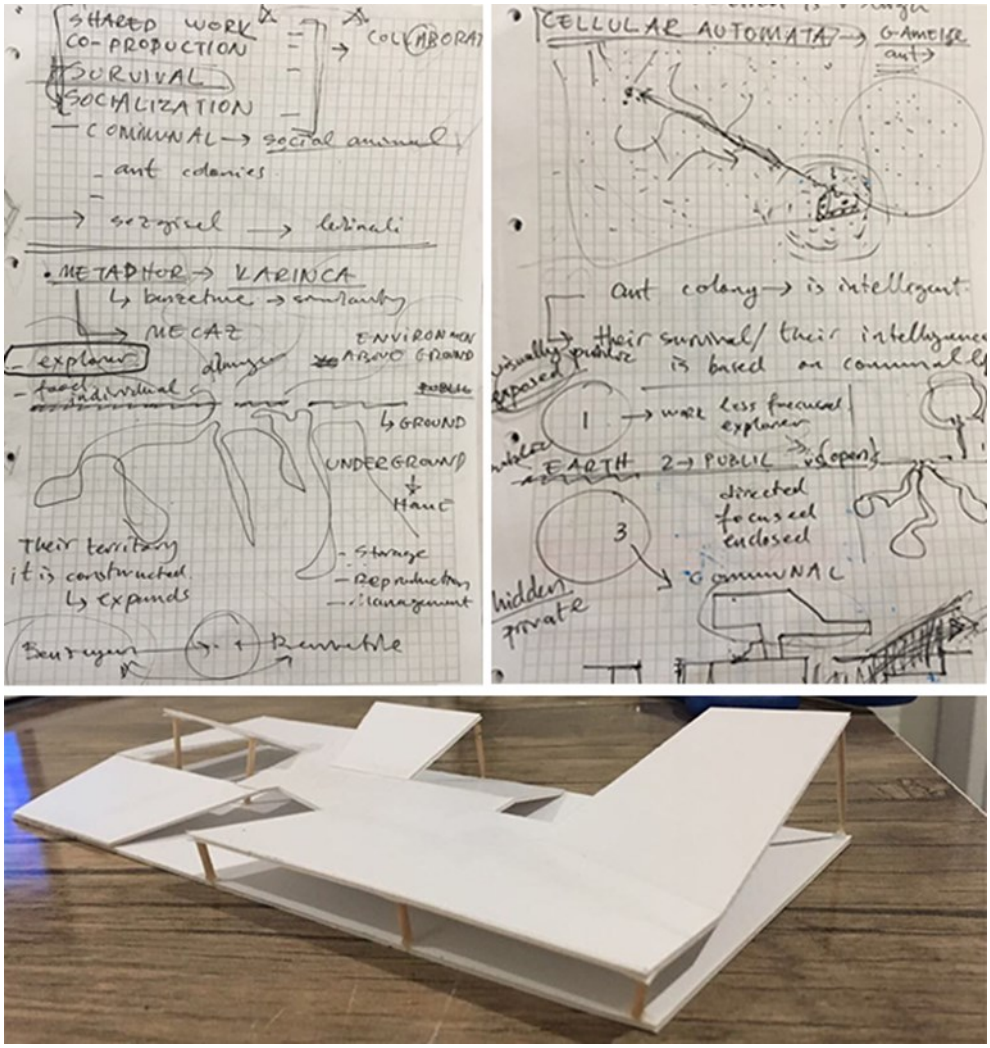


Figure 23: Proposals of Instructor 1

After the desk critique, student made a new digital model (Figure 24), which he explained as follows:

> The instructor made a model at the desk critique. And then, I converted it in the digital environment.

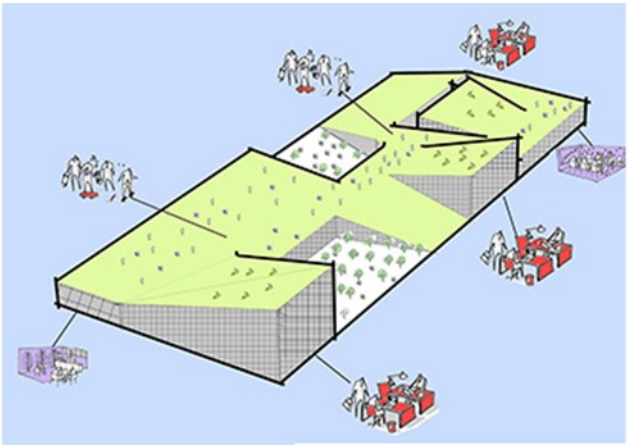


Figure 24: Digital model of Student 2

Student presented this digital model and the model of Instructor 1 at the desk critique with Instructor 2. Instructor 2 changed the paper model and he made a sketch (Figure 25). In addition, he suggested some conceptual ideas. Student related the following with regard to this critique:

> The instructor trimmed the model at the desk critique. He said that the model did not get natural light. However, I did not like the new model. I thought that the shell idea lost its significance by all the trimmings. Therefore, I did not continue this model. Also, Instructor 2 said that the project form is inadequate in terms of square meters.

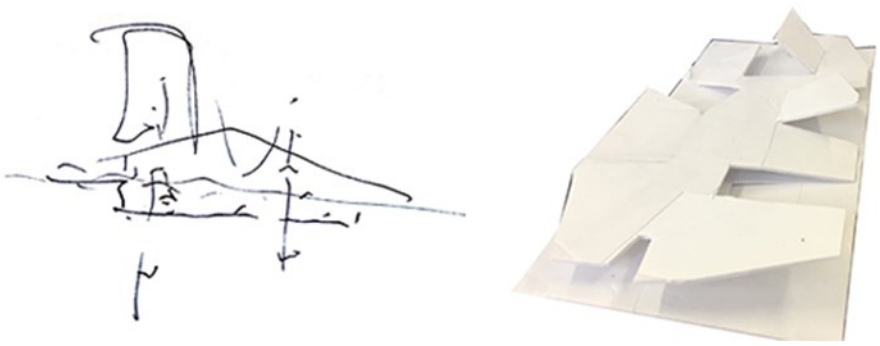


Figure 25: Proposals of Instructor 2

Instructor 2 explained this process as follows:

> The model of the student had a problem of getting in light. I said that this problem should be solved. I made a sketch about the light solution. I indicated that there should be holes on the shell. I trimmed his model to show the solution. Also, I said that this form is inadequate in terms of square meters.

After the desk critique, student worked on square meters and the shell. He prepared an abstract model showing the square meters and a model (Figure 26). The student explained the changes he made as follows:

> I worked on square meters and the form. I made a model by raising sloping surfaces for adding square meters.

Figure 26: Square meters model and model of Student 2

Student prepared a new set of materials to present at the midterm jury. These representations were sections, diagrams, and a model (Figure 27). After the midterm jury, Instructor 2 made a sketch to show his idea to the student (Figure 28) which the student understood as follows:

> Instructors mentioned the light problem. And they did not like the holes on the shell. They suggested that the holes should be small. They said that the form was inadequate in terms of square meters. Also, they did not think of the indoor-outdoor relation as spatial enough.

Instructor 1 explained their reaction to the new scheme:

> I said that the shell-space relation was weak. I indicated that this relation should be stronger. I suggested a program activity for the top of the shell. Also, I suggested inner gardens to increase the indoor-outdoor relationship.

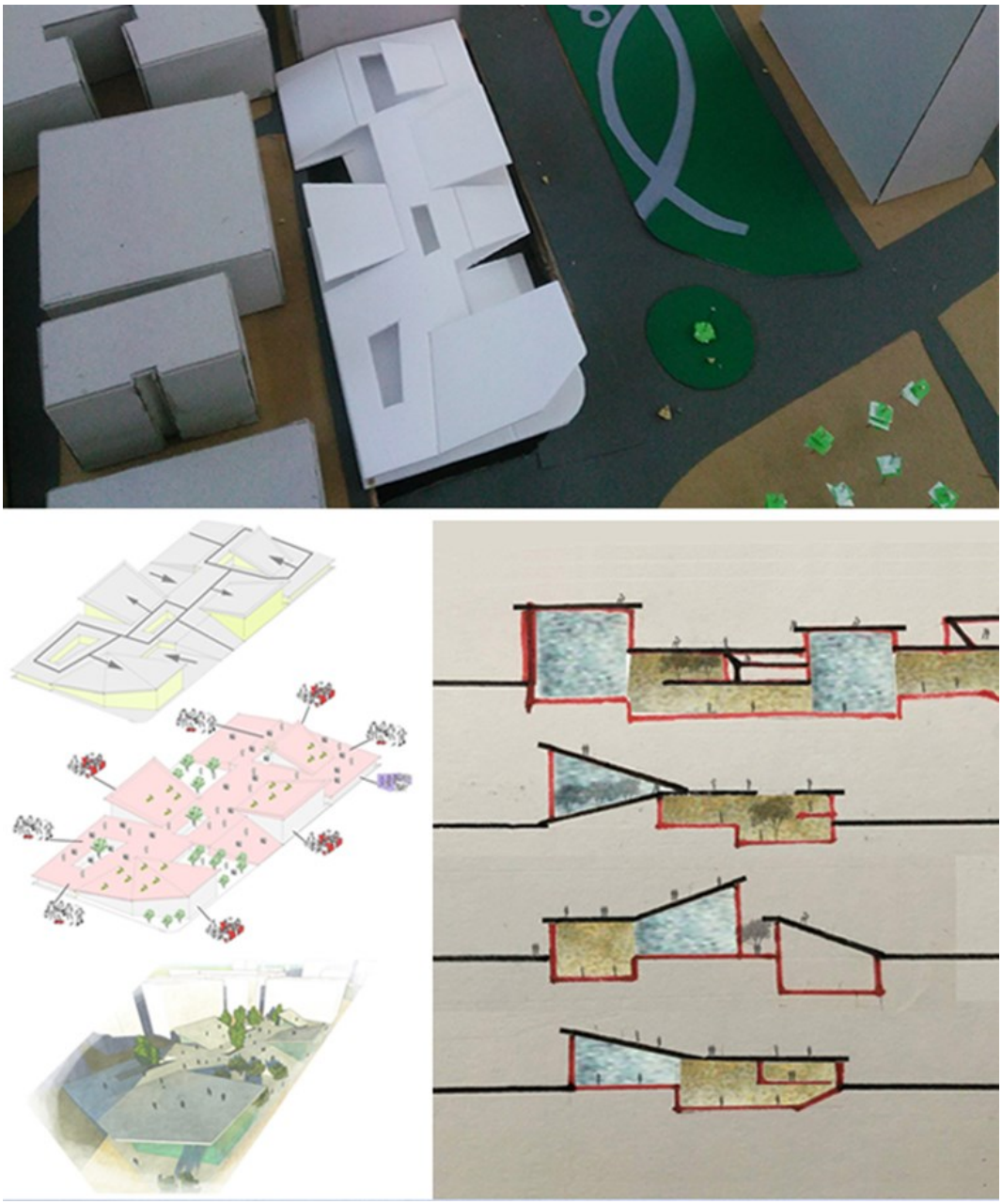


Figure 27: Midterm jury representations of Student 2

Instructor 2 stated the following:

> I said the project was still inadequate to get light, and I said that the holes on the shell were random. I think it's wrong to have big holes on the shell. For this reason, I proposed small holes and then I made a sketch. I also stated that the form was still inadequate in terms of square meters.

The student continued to work after the midterm jury and he made a new model (Figure 29). He presented this model at the desk critique with Instructor 1. Instructor 1

suggested some conceptual ideas and gave the example of *CCTV Hotel Building* by Rem Koolhaas as a precedent (Figure 30). The student explained this model as follows:

> After the midterm jury, I checked the square meters again and I decided to add a tower because the square meters were insufficient. I added a tower and I placed workspaces in this tower. However, I had no idea about the form of the tower. I made an angled form to make it compatible with the form of the shell.

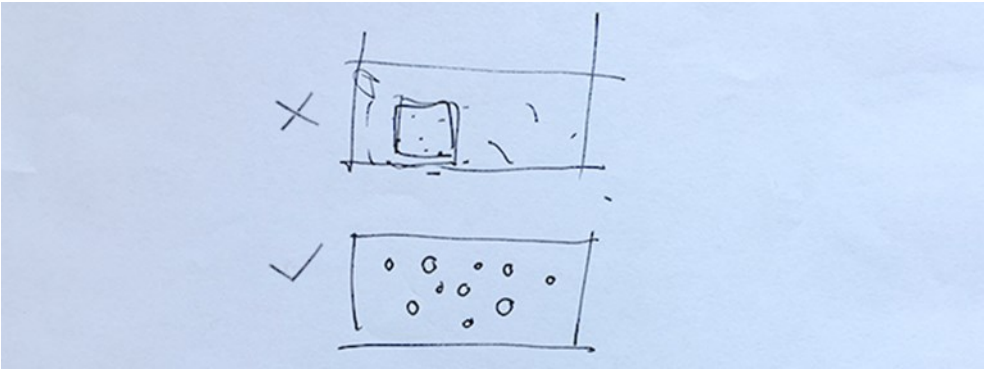


Figure 28: Proposals of Instructor 2 in midterm jury

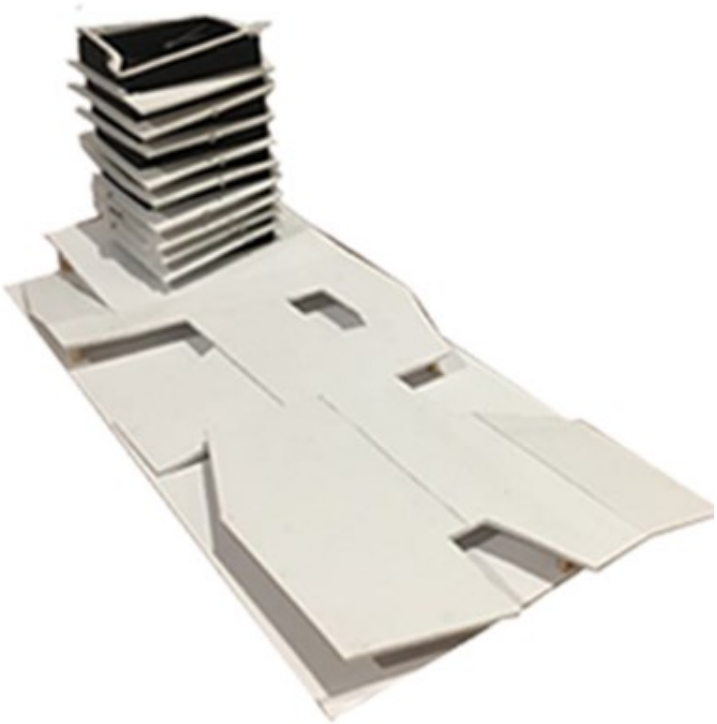


Figure 29: Model of Student 2

Figure 30: CCTV Hotel Building by Rem Koolhaas
(Source: Architectural Record website, 2018)

Instructor 1 explained the following:

> I said that the form of the tower as it was in the last model was not in harmony with the shell. I mentioned that the shell should wrap the tower. I suggested spaces which worked with shell to provide spatial relations. Also, I gave an example for the shell form.

After the desk critique, student prepared a new set (Figure 31) which he put it in the following words:

> After the desk critique, I wrapped the tower with the shell. Then, I prepared a model, plan, sections, elevations and 3D render. Instructors liked my project.

Instructor 1 reported that the last phase of student's project was good but had some shortcomings in the sense that the scheme "could not provide enough indoor-outdoor spatial relations". Instructor 2 added:

> The student did not want to make concessions from the form from the beginning of the process. For this reason he did not make any changes to the form. He always worked with a model. He did not draw a section until almost at the end. I think this was a very strange situation. For this reason, I think that the project had failed in terms of spatial organization. I think it was a deduction project. He made a shell and he tried to fill it. I think it was not a successful project. I think it is a very reductive approach to develop the project through a single element for mix-use. I think the student was not aware of what he did and what the metaphor was about. He could not solve the light problem also he could not provide spatial relations in shell.

Instructor 3 stated the following:

> I almost did not give any critique to this student because he did not want to talk to me. Therefore, I did not have a grasp of the project. I think the end product was not bad.

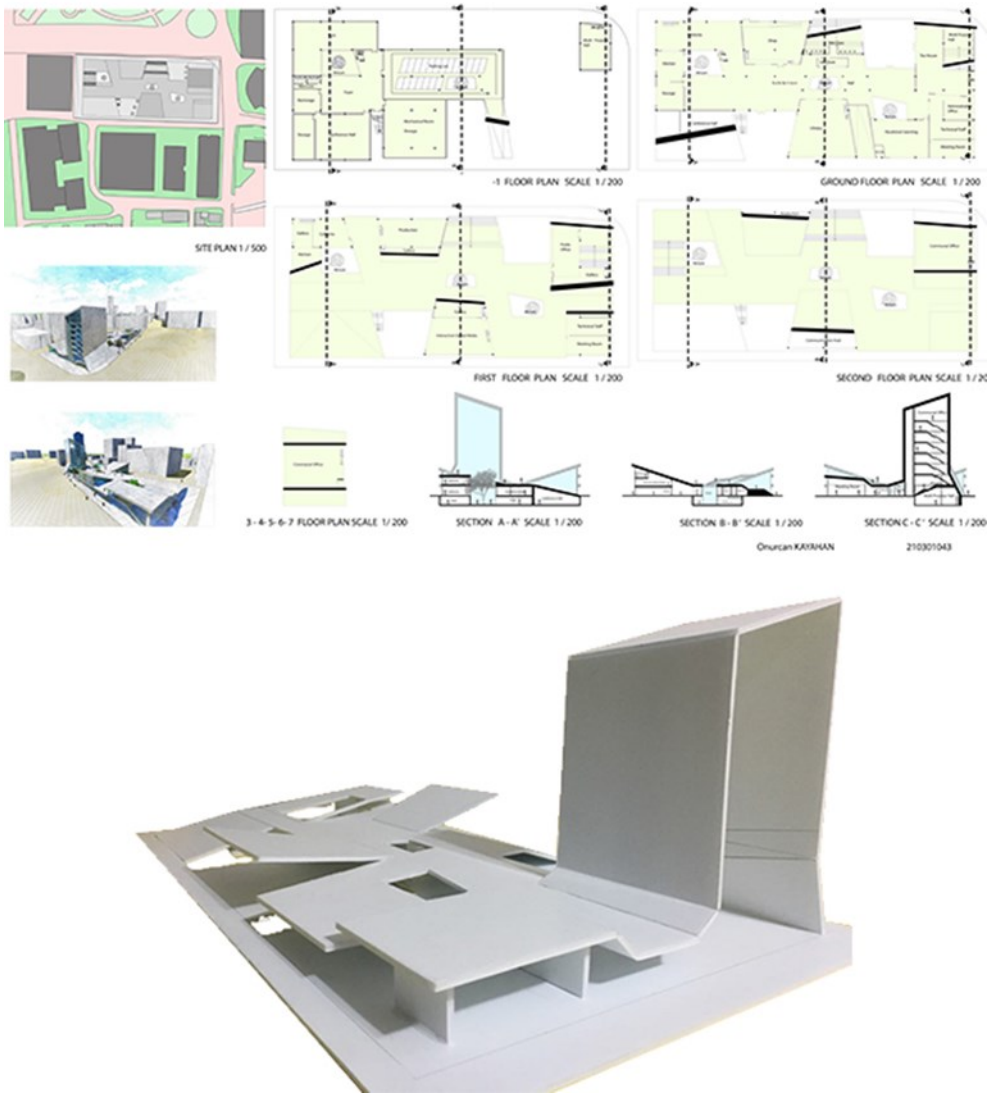


Figure 31: New set of Student 2

Instructor 4 offered the following:

> Student did not take a critique in the conceptual development process of the project. I followed the process at juries. I think that student did not change the project so he did not take a critique. I think it was a nice project although there were some problems.

4.2.2. Interpretation

In this section, the conceptual development process of the student's project is examined in five steps. These steps are Step 1 - Panel Review, Step 2 – Desk Critique with Instructor 1, Step 3 – Desk Critique with Instructor 2, Step 4 – Midterm Jury, and Step 5 – Desk Critique with Instructor 1.

Step 1 – Panel Review

The student developed a concept about collaborative work which was inspired by an ant colony. The process of the student (Figure 32) is summarized graphically and in a table (Table 6) as follows:

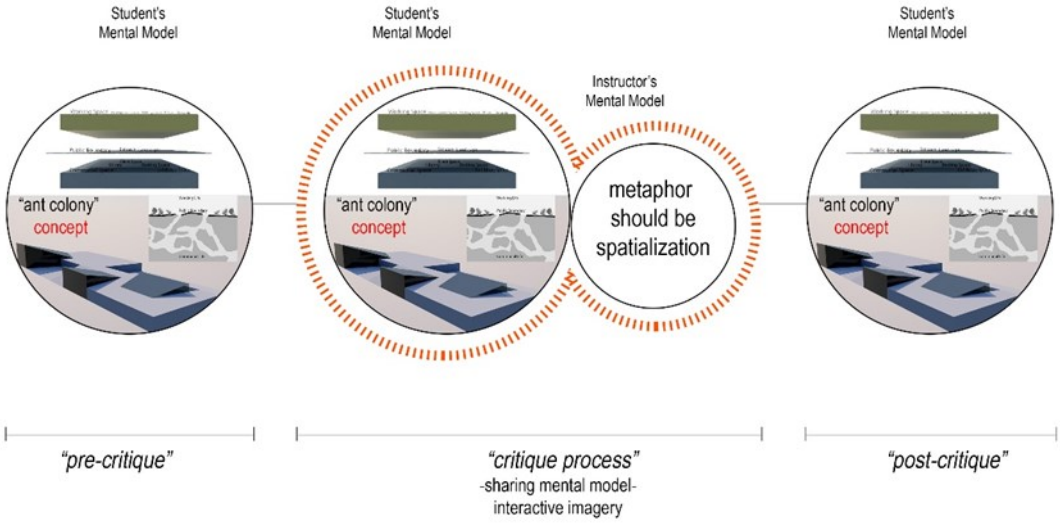


Figure 32: Step 1 of Case 2

Table 6: Step 1 of Case 2

Step1	**Type of Reasoning**	**Type of Transformation**
Student	x	x
Instructor 1	seeing as	x

The student did not make any changes in his project after the first critique therefore it is hard to comment on what he took from the first critique. Instructor 1 further the ant colony metaphor for the project. He explained how the metaphor would be spatialized and mentioned that topography and shell could design components in his scheme. He suggested that he should think about the concept and he should reflect it on the form and the spaces. Therefore, at this point, instructor's reasoning type can be interpreted as "seeing as".

Step 2 – Desk Critique

Student presented the same materials at the desk critique with Instructor 1 (Figure 22). Instructor 1 repeated the same suggestions which were mentioned at panel review

and made a sketch and a paper model to explain his ideas (Figure 23). The student prepared a digital model after the desk critique (Figure 24). The process of the Step 2 (Figure 33) is summarized (Table 7) as follows:

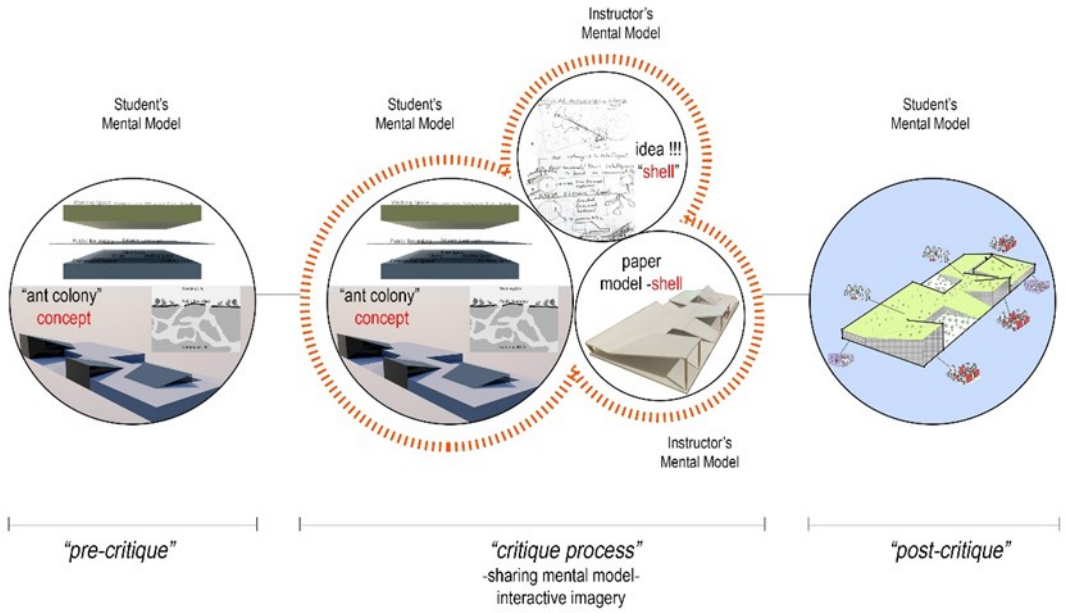


Figure 33: Step 2 of Case 2

Table 7: Step 2 of Case 2

Step 2	**Type of Reasoning**	**Type of Transformation**
Student	seeing that	lateral transformation
Instructor 1	seeing as	lateral transformation

Instructor 1 made a model during the desk critique. The student made the same model in the digital environment. In other words, he did not make any conceptual changes in the scheme. Therefore, the type of reasoning of the student in this process can be interpreted as "seeing that". On the other hand, the change between the first representation of the student and the second representation of the student can be interpreted as a "lateral transformation". The reason is that there was a conceptual and formal difference between the first proposal and the second proposal. There was a metaphor in the second proposal. He created a topography in the form of a shell in his second proposal.

At this critique, the instructor's reasoning type can be interpreted as "seeing as" because he suggested conceptual changes. On the other hand, the change between the

representation of Instructor 1 and the representation of the student can be interpreted as a “lateral transformation”. The reason for this is that the proposals are conceptually different from the representation of the student.

Instructor 1’s suggestions offer a conceptual approach to the student’s project. Instructor 1 presented the knowledge that will affect the conceptual development of the project. The student developed a new conceptual approach using this knowledge. For example, the shell idea and metaphor. For this reason, it is possible to interpret the learning style of the student at this step as “conceptual learning”.

Step 3 – Desk Critique

The student presented a digital model (Figure 24) and the model built by Instructor 1 (Figure 2) at the desk critique with Instructor 2 who trimmed the model and he made a sketch to explain his ideas (Figure 25). The process of the Step 3 is summarized in Figure 34 and Table 8.

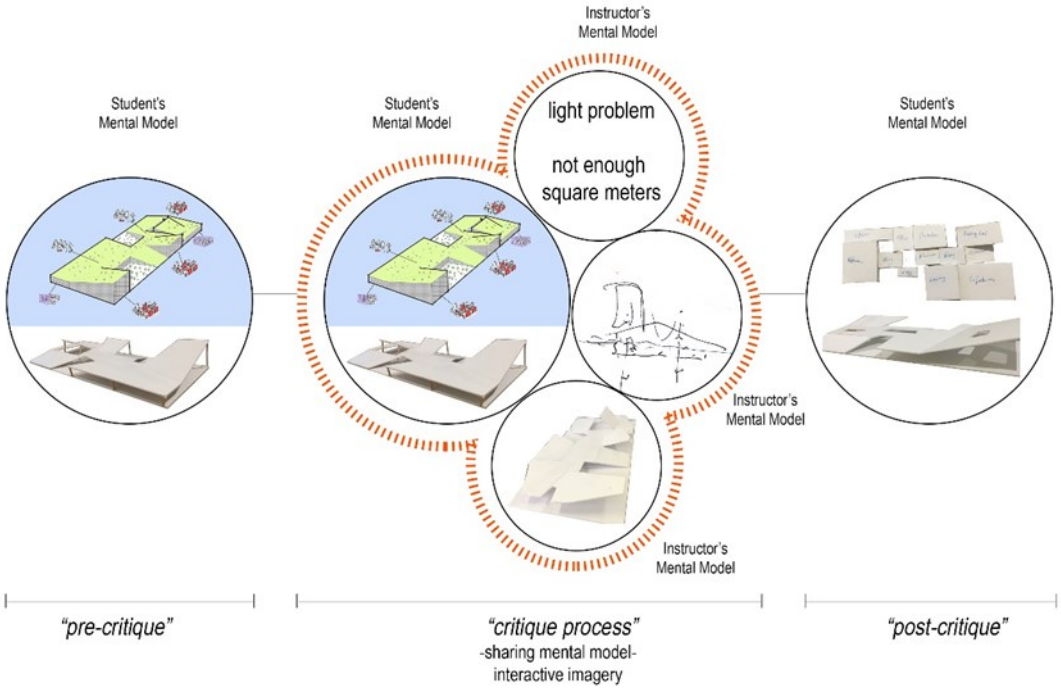


Figure 34: Step 3 of Case 2

At the desk critique with Instructor 2, student’s reasoning type can be interpreted as “seeing as” because he thought of a different conceptual approach to solve the light and square meters problems.

Table 8: Step 3 of Case 2

Step 3	**Type of Reasoning**	**Type of Transformation**
Student	seeing as	lateral transformation
Instructor 2	seeing that	vertical transformation

On the other hand, the change between the first scheme and the second scheme can be interpreted as a "lateral transformation". The reason is that student reflected conceptual changes in the new scheme. Instructor 2's reasoning type can be interpreted as "seeing that" because he suggested a new solution for the same shell. The change between Instructor 2's scheme and the student's scheme can be interpreted as a "vertical transformation". The reason for this is that the instructor made changes on the same shell and he did not suggest a conceptual change.

Instructor 2 suggested a procedural knowledge during the desk critique. These pieces of knowledge were related to the light problem and inadequacy in square meters. Student prepared a new model and square meters model by using these knowledge. Therefore, it is possible to interpret the learning style of the student at this step as "professional learning".

Step 4 – Midterm Jury

Student prepared a new set of material for the midterm jury (Figure 27). Instructor 2 made a sketch to explain ideas after the midterm jury (Figure 28) which resulted in a new model (Figure 29). This step (Figure 35) is interpreted in the light of the knowledge obtained from the interviews (Table 9) as follows:

At the midterm jury, instructors 1 offered new conceptual ideas. After the midterm jury, the student added a tower and he placed workspaces in this tower. At this point, the student's reasoning type can be interpreted as "seeing that" because he could not add conceptual differences. In addition to these, the student's scheme changed by a "vertical transformation" because he did not make any conceptual changes in the new the model. He added a tower to solve the square meters following the same concept. Instructor 1 said that the shell-space relation was weak. At this point, his reasoning type can be interpreted as "seeing as" because he talked about conceptual differences.

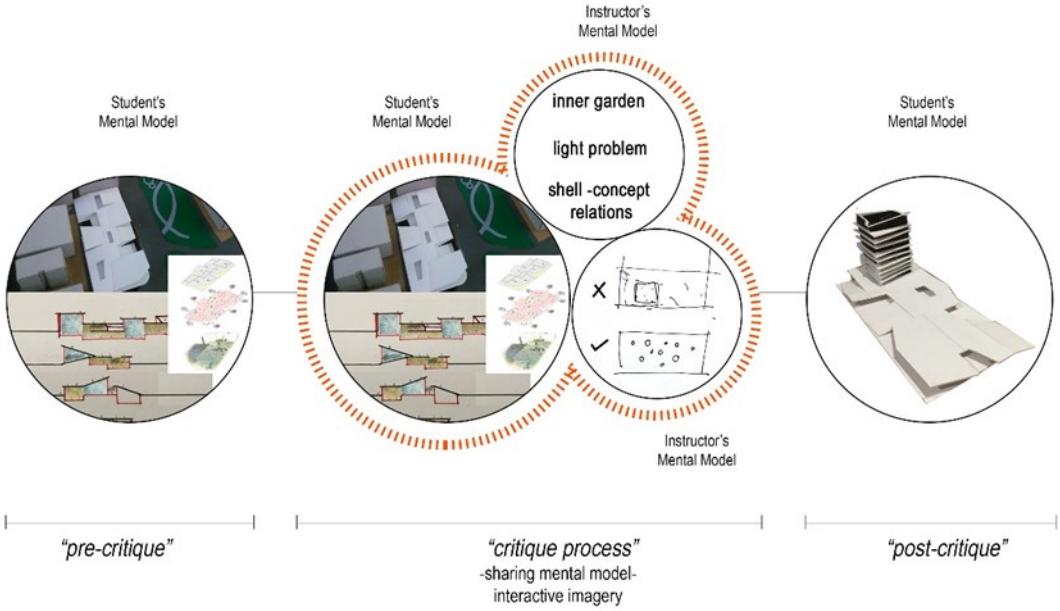


Figure 35: Step 4 of Case 2

Table 9: Step 4 of Case 2

Step 4	**Type of Reasoning**	**Type of Transformation**
Student	seeing that	vertical transformation
Instructor 1	seeing as	x
Instructor 2	seeing as	vertical transformation

Instructor 2 related that the project was still inadequate for light, and he said that the holes on the shell were random. His reasoning at this stage can be interpreted as "seeing as" because he presented a different perspective (in relation to indoor space). In addition to these, the difference between Instructor 2's and the student's schemes can be interpreted as a "vertical transformation" because he suggested small holes in the same shell. In other words, he did not propose a different conceptual approach for the shell.

Instructor 1 presented some conceptual knowledge. These were shell-space relation, program for the top of the shell, and inner gardens. Instructor 2 presented procedural knowledge. These were light problem, dimension of holes, and inadequate square meters. It is possible to interpret the learning style of the student at this step as "professional learning" because he used only the procedural knowledge in the new scheme.

Step 5 – Desk Critique

At this last step the student introduced a tower that housed the work spaces wrapped with the shell and this step is diagrammatically summarized (Figure 36) and tabulated (Table 10) as follows:

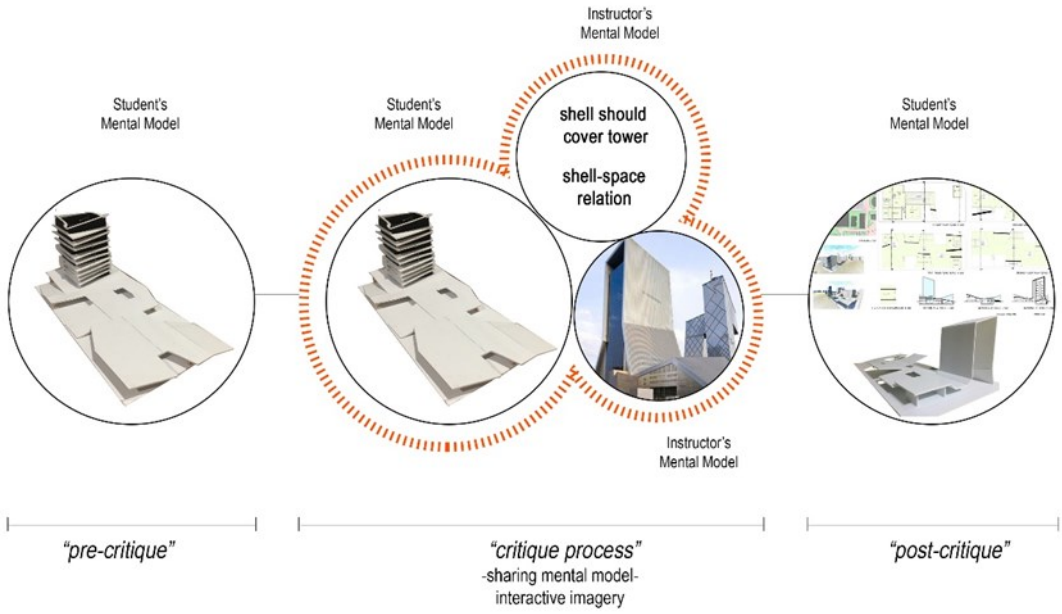


Figure 36: Step 5 of Case 2

Table 10: Step 5 of Case 2

Step 5	**Type of Reasoning**	**Type of Transformation**
Student	seeing that	vertical transformation
Instructor 1	seeing that	vertical transformation

The student's reasoning can be interpreted as "seeing that" because he did not make any conceptual changes in the project. He only wrapped the tower with the shell. Therefore, the change can be interpreted as a "vertical transformation". Instructor 1 mentioned that the shell should wrap the tower. At this point, the instructor's reasoning type can be interpreted as "seeing that". It is possible to interpret the change in the instructor as a "vertical transformation" because he proposed only formal changes.

Instructor 1 presented conceptual knowledge in this step. These were related to the form of the tower and spatial organization. The student used only one of them (form of tower) in the new scheme. Therefore, it is possible to interpret the learning style of the student at this step as "conceptual learning".

4.2.3. Discussion

In this section, Case 2 is discussed in terms of cognitive components of design, i.e., representation and reasoning.

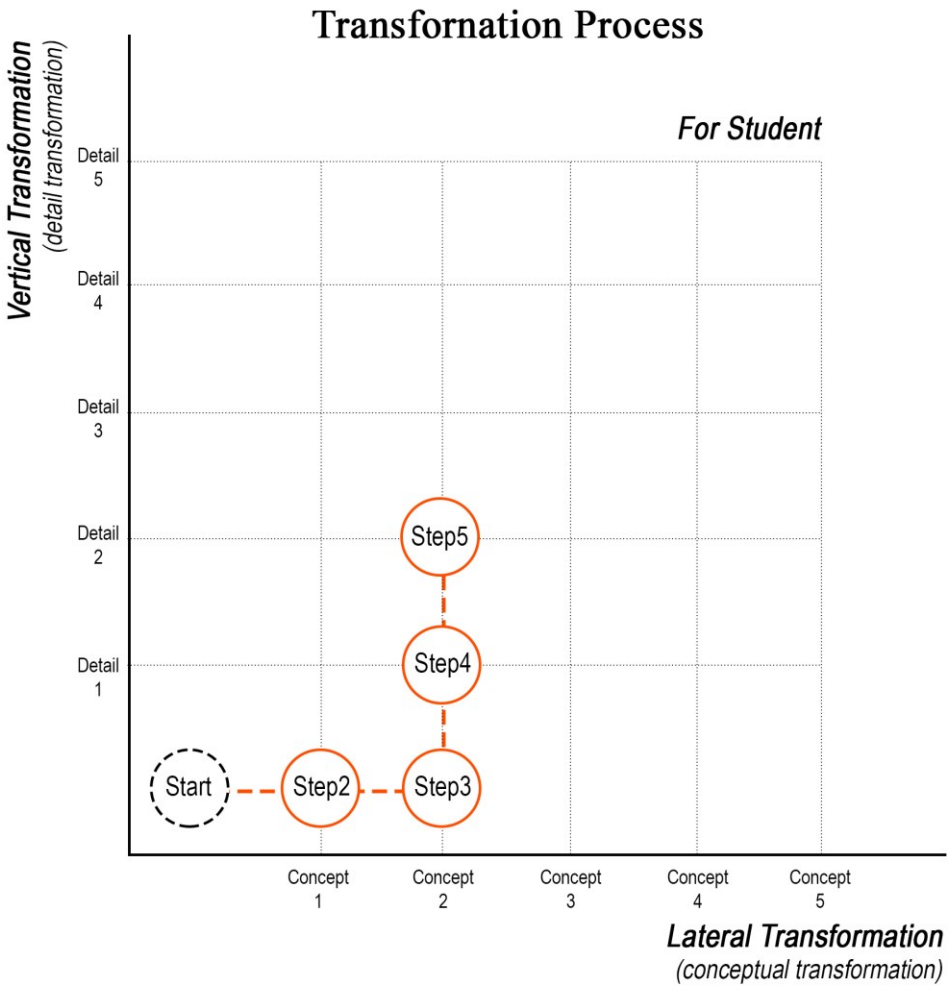
Representation

In this case, the student achieved a final product through both lateral transformations (in Step 2, and Step 3) and vertical transformation (in Step 4, and Step 5) in the project development process (Figure 37). It is possible to say that in the middle of the process, the student had a conceptual shift triggered by critiques. Instructors used mostly vertical transformation (in Step 3, Step 4, and Step 5). It is possible to interpret that instructors offered changes that would improve student's conceptual idea rather than a radical shift from his initial concept.

Reasoning

Student's pictorial reasoning is mostly "seeing that" (in Step 2, Step 4, and Step 5) (Figure 37). It is possible to say that the student did not make conceptual changes during the majority of the process. In terms of instructors, they used mostly "seeing as". It can be stated that they proposed a new conceptual approach by recalling knowledge based on the student's representation as stimuli.

Briefly, in this case, the student began the project with a concept and form. During the conceptual development process of his project, he did not make many changes to the form of the project. Actually, he did not want to change the form of the project because he liked it. He did not reflect the conceptual and technical requirements in his project because he did not want to change the project radically. At this point, it is possible to interpret that the student did not take into consideration instructors' proposals at the jury, panel review and desk critiques. Instructors proposed different perspectives to develop the project conceptually at the jury, panel review and desk critiques (Figure 38). However, the student did not respond to all these suggestions. In this case, interactive imagery remained limited with the initial image proposed by the student. During the project process, he made little changes in both conceptual and technical aspects of his project.



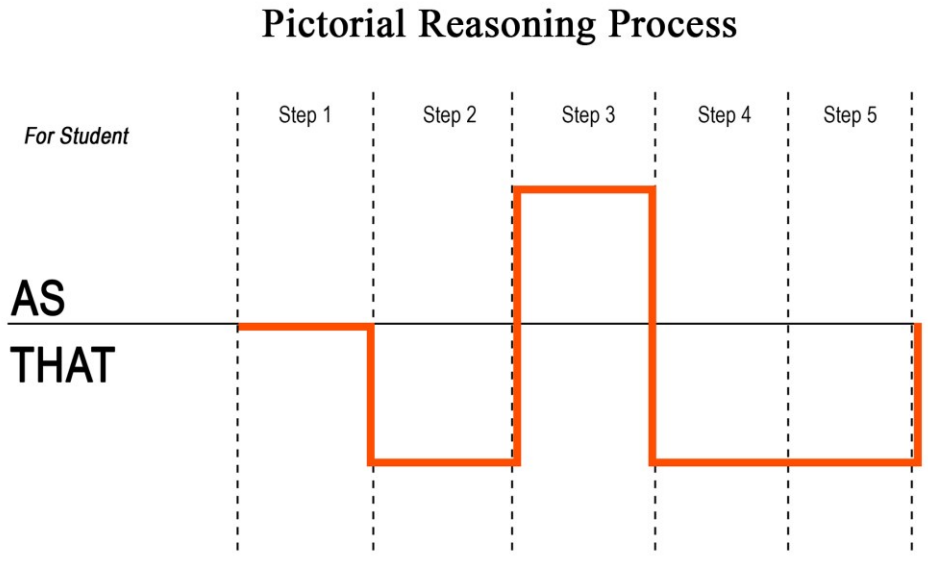


Figure 37: Transformation Process and Pictorial Reasoning Process of Case 2

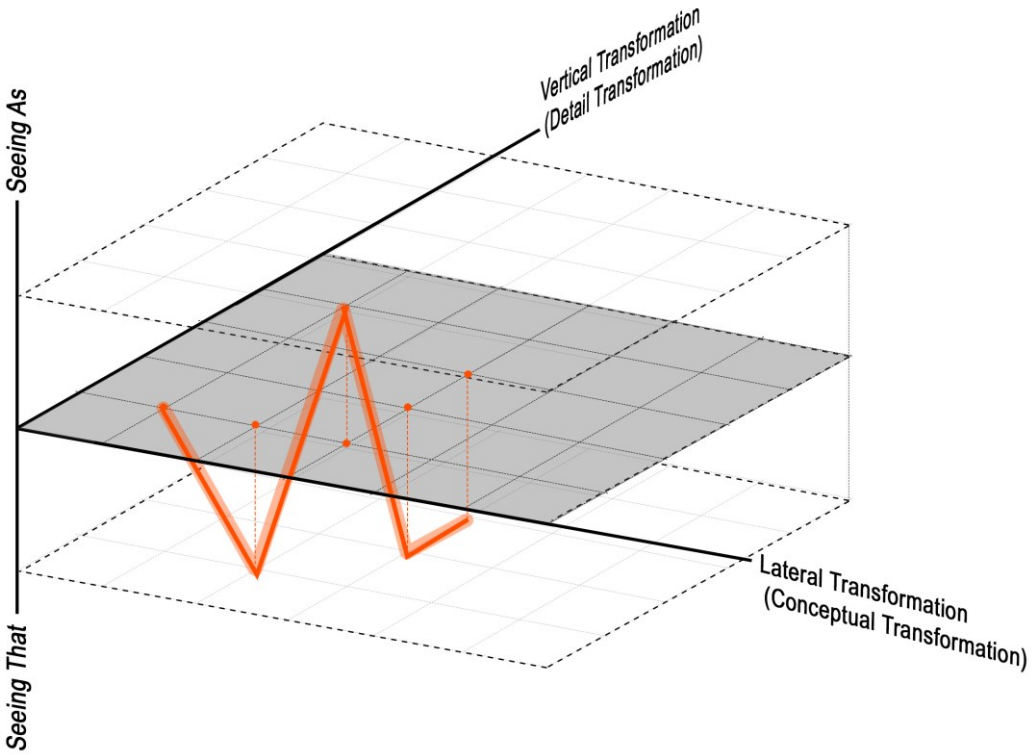


Figure 38: Design Path of Case 2

4.3. Case 3 - Student 3

Student 3 adopted a "follower" attitude in his project process. He changed his initial concept after the instructors' suggestions. He took into consideration the instructors' suggestions during the process. However, he did not make an extra effort in adapting the suggestions to the project. In other words, he did not mix the instructors' suggestions with his own ideas. Student 3 changed the project by copying the suggestions of the instructors.

4.3.1. Process

Different from the previous two students, this student could not attend the panel review and discussed his first proposal the desk critique with Instructor 4 (Figure 39). The proposal of the student was shaped along a "pedestrian axis". The student explained his idea as follows:

> First of all, I studied the city morphology in Bayraklı. There were roads and buildings in the district. There was almost no pedestrian axis. Vehicle roads were blocking the pedestrians' movement. I wanted to propose a pedestrian road to solve this problem. Then, I thought about how to combine a pedestrian axis with work. Then, I found the idea of creating a pedestrian axis. I designed this axis which divided the mass of the building.

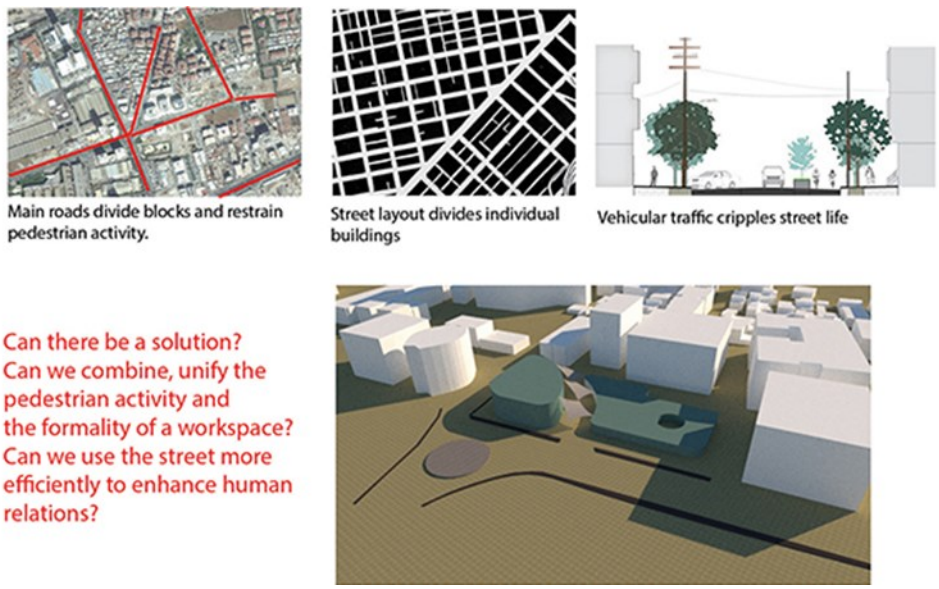


Figure 39: Representations of Student 3

He also had this to add about the desk critique:

> The instructor told me that "you designed it like a street but if you do something about the activity, the axis should affect the inside of the building." In addition to this, she asked me that "Is it right to separate the masses from each other?" She stated that the relationship between the two masses should be well established.

Instructor 4 explained the desk critique process as follow:

> I gave the first desk critique to the student. He did not attend the panel review due to personal reasons. Therefore, I saw the project for the first time. He wanted to design a pedestrian axis. He mentioned that he wanted to connect work with the pedestrian activities. He did not have spatial organization ideas about this concept. I said "you should think about this situation." I suggested that connector idea should be used in the spatial organization.

After the desk critique, the student did not make any changes to his project. He presented the same material at the following desk critique with Instructor 1 (Figure 39). Instructor 1 offered that the scheme could be reinterpreted in terms of the valley metaphor and made a paper model to illustrate these (Figure 40). The student stated "the instructor suggested an "artificial valley" to connect the work space and the pedestrian path. Also, he made a paper model."

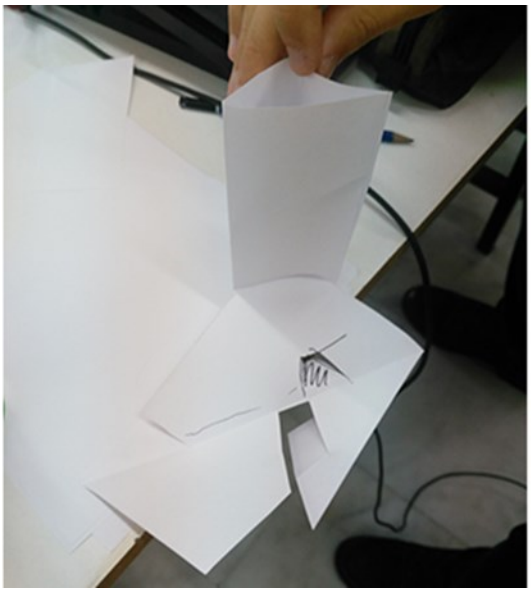


Figure 40: Paper model of Instructor 1

Instructor 1 explained the desk critique process as follow:

> Student wanted to connect the street life and the work spaces. Instead, he had isolated work and pedestrians. I said that the pedestrian axis should be a connector. Then, I suggested the "artificial valley" metaphor and I made a paper model to illustrate this idea.

After the desk critique, the student continued to study with the metaphor of "artificial valley". He prepared a new set of representations and presented these at the midterm jury (Figure 41). Instructor 2 gave an example *TWA Flight Center* by Eero Saarinen as a precedent (Figure 42). In the interview, the student explained this as follows:

> I presented a new concept. I touched upon the urban sprawl in Bayraklı. There were slums on one side and skyscrapers on the other side. There was a chaos. I wanted to design a project that will affect the silhouette at the minimum level. Therefore, I started the project with the artificial valley idea. I divided public and private spaces through pedestrian axis that goes through the middle of the valley. I placed public spaces along the pedestrian axis.

Instructor 2 explained the midterm as follows:

> Student attached two triangles... I think it was a disastrous thing. He said "I propose an artificial valley". However, there was no valley. There were many problems in this project. I think it was meaningless to cut a rectangle diagonally. I suggested that the valley idea should be metaphor. Also, I said that the slopes of the valley looked like wings. In addition to these, I think the pedestrian axis which was in the middle of valley, was like a "the straight path". I mentioned that the project was bad. Also, I gave an example about how the metaphor could be converted in the scheme.

Instructor 4 remembered it as follows:

> I said that the pedestrian axis is too thin. It should be thicker. Also, I asked “why the pedestrian axis is diagonal” I mentioned it should be changed.

The student, in return, explained the midterm as follows:

> Instructors did not like the form. Also, they said that the slopes of the valley are like bird wings. They offered a metaphor and one of them gave an example.

After the midterm jury, the student made some changes to the model and he made a sketch. He presented these at the desk critique with Instructor 3 (Figure 43) which he explained as follows:

> I tried to change the model because instructors did not like it. I thickened the pedestrian axis. I tried to change the slopes of the valley but I could not do it properly. I made a sketch to show what I wanted.

Instructor 3 suggested some ideas also and gave an example, i.e., *Office Park* by Emre Arolat (Figure 44):

> I reminded him of the work-concept relation because it was not obvious how the “valley” is linked to “work”, there was no spatial proposal. I mentioned that "you should think conceptually." Also, I gave an example about work space-public space relation. In addition to these, I said that square meters and program relation should be considered.

Figure 41: Midterm representations of Student 3

Figure 42: TWA Flight Center by Eero Saarinen
(Source: Uncrate website, 2018)

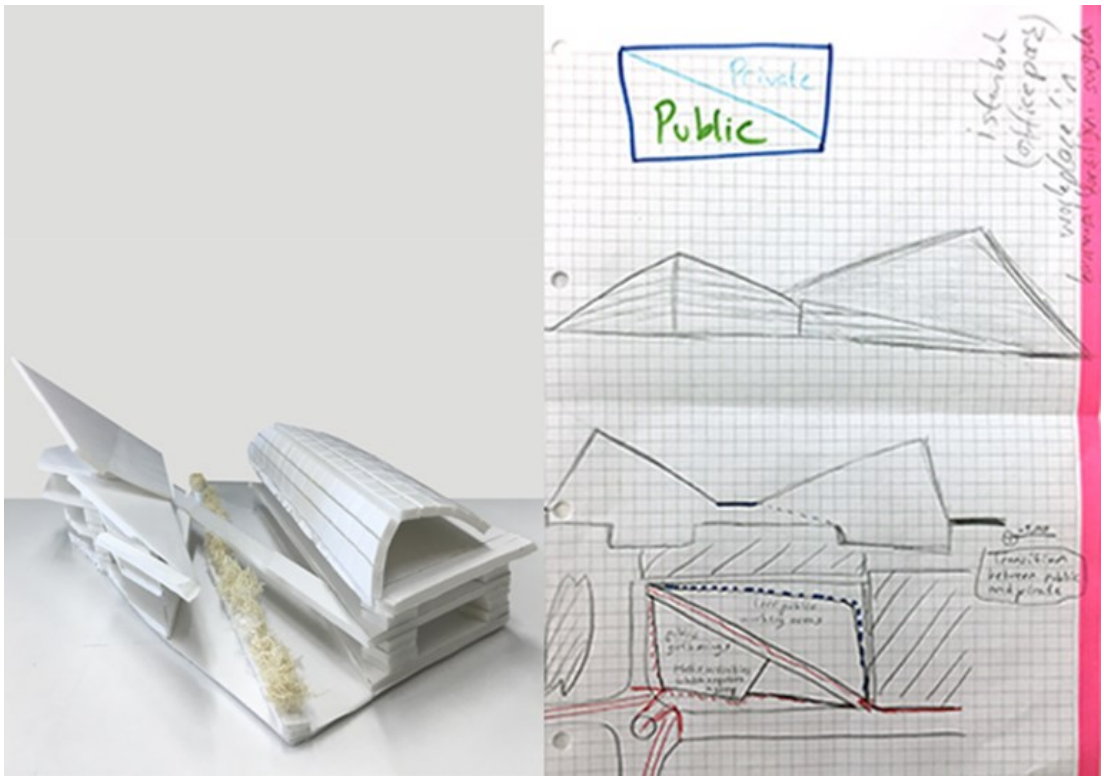


Figure 43: Model and sketches of Student 3

Figure 44: Office Park by Emre Arolat
(Source: Emre Arolat Architecture website, 2018)

The student understood the following from the desk critique:

> The instructor mentioned that the metaphor should be reflected in the space and form. He suggested that the relationship between the valley and the work spaces should be stronger. He said that square meters and program relations should be reconsidered. Also, he gave an example.

After the desk critique, student prepared a new model and he made a sketch plan (Figure 45):

> I worked on spaces after the desk critique. I considered the program and square meters. I decided to replace the slopes of the valley with terraces by changing the mass organization. Then I made a new model. This model was different from the other because first I thought about the organization of the spaces but I always kept the valley idea. I placed a tower on one side because of inadequate square meter.

The student presented the model and a sketch plan at the desk critique with Instructor 1 (Figure 45). Instructor 1 suggested ideas and he sketched over student's sketch plan (Figure 46). Instructor 1 explained the desk critique as follows:

> I mentioned that the previous form had more potential. I said that "you should focus on the metaphor and the valley idea." I offered that to think of the slopes and the valley as topography would help him to create the mass. I broke the orthogonal geometry in the sketch plan following the general outline of a pedestrian axis cutting the site diagonally. In the sketch plan, red lines are mine. Also, I suggested that "you should consider topography and program together".

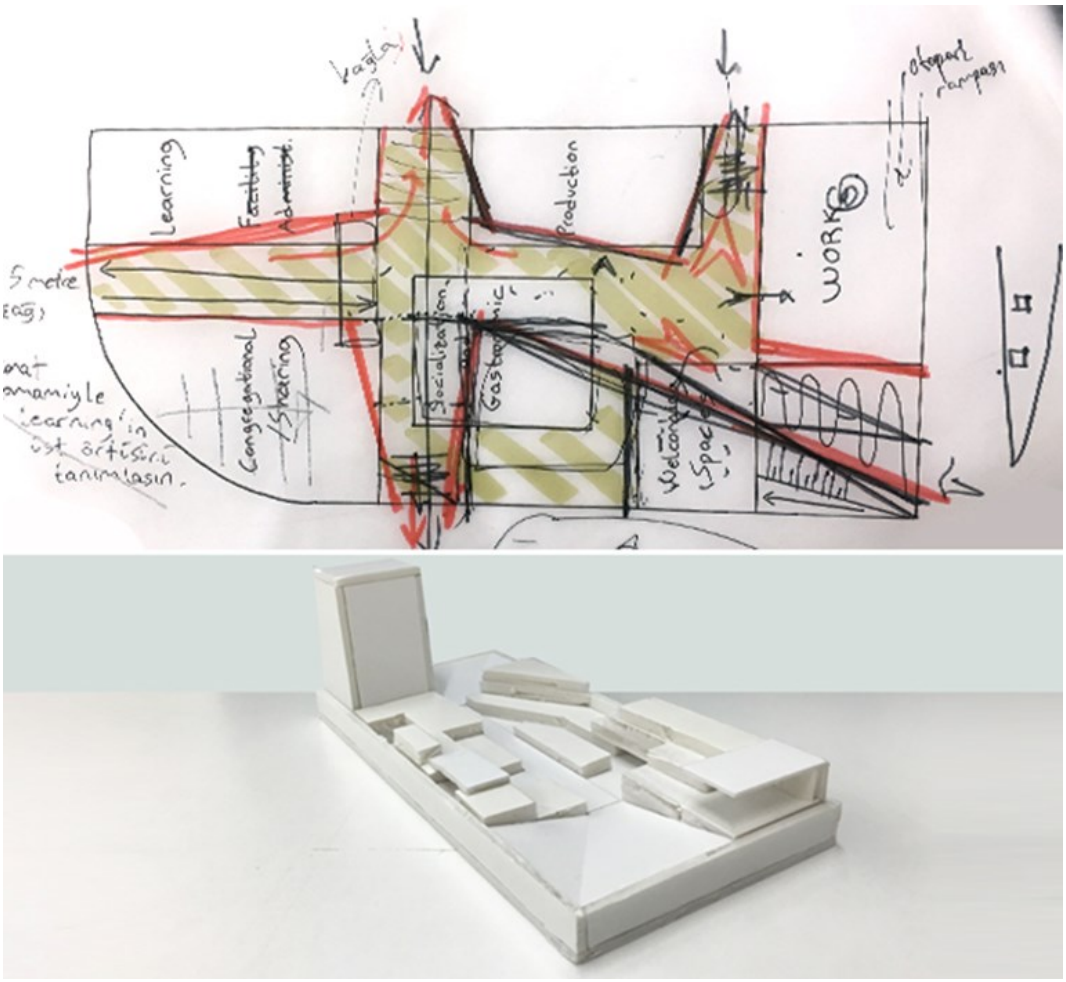


Figure 45: Model and sketch plan of Student 3

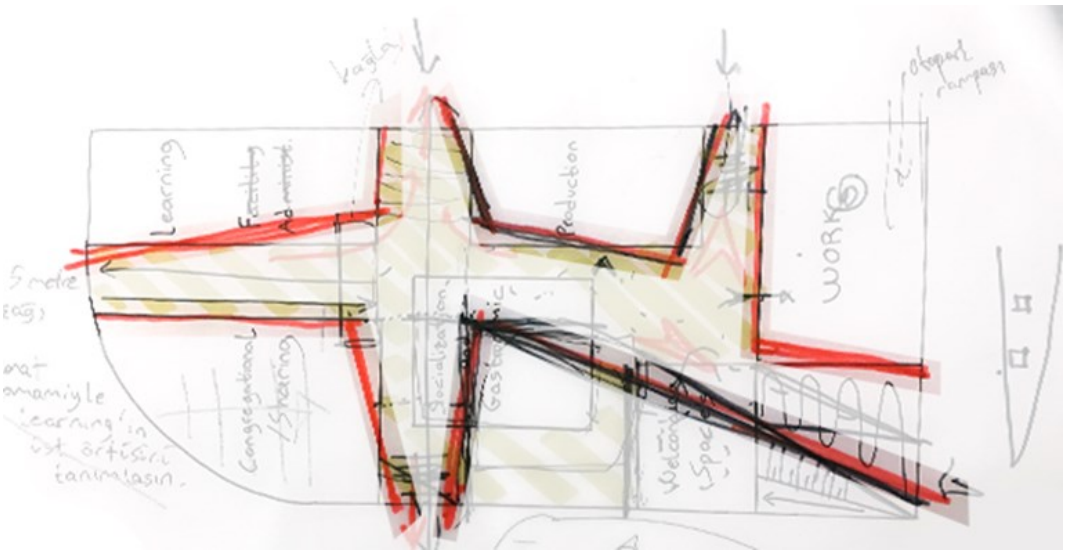


Figure 46: Proposal of Instructor 1

The student related the following about this critique:

> The instructor said that "you should keep the valley idea". He drew lines on my sketch plan. Then I copied these lines and I made a layout for the model and ground floor plan.

After the desk critique, student prepared a new model, plan, and section drawings (Figure 47). Therefore, student completed the conceptual development process of his project with this last proposal. He stated that he liked the project and that "[he] was able to realize [his] idea. [He] could not separate the public from private but [He] always kept the valley idea."

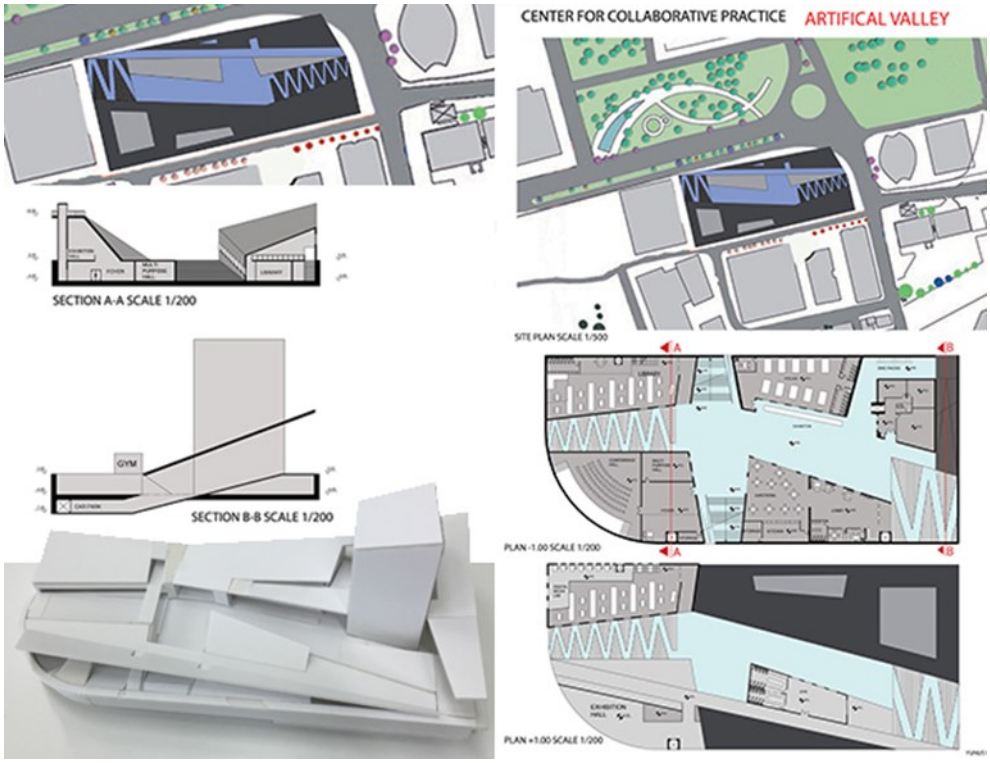


Figure 47: Representations of Student 3

Instructor 1 thought that the scheme "was not as good as it could get" but that he "tried to reflect the concept." Instructor 2 stated the following:

> I think the student did not understand the metaphor. Also, I did not understand why the student selected the valley concept because I think there was no relation between works space and valley. I never approved the form of the project and I did not like it. I always saw the valley as a metaphor, but the student always saw it as a form. The student almost never took a desk critique from me during the conceptual development process.

Instructor 3 stated “the relation between valley and work did not work together so the project was not successful. Actually, in terms of form, the project had more potential but the student could not notice these potentials.” Instructor 4 added:

> Student always considered the form and he did not think conceptually. Therefore, he could not reflect the concept onto the project.

4.3.2. Interpretation

In this section, the conceptual development process of the student’s project is examined in five steps. These steps are Step 1 – Desk Critique with Instructor 4, Step 2 – Desk Critique with Instructor 1, Step 3 – Midterm Jury, Step 4 – Desk Critique with Instructor 3, and Step 5 – Desk Critique with Instructor 1.

Step 1 – Desk Critique

The proposal of the student was shaped around a “pedestrian axis”. The process of the student is summarized graphically (Figure 48) and in a table (Table 11) as follows:

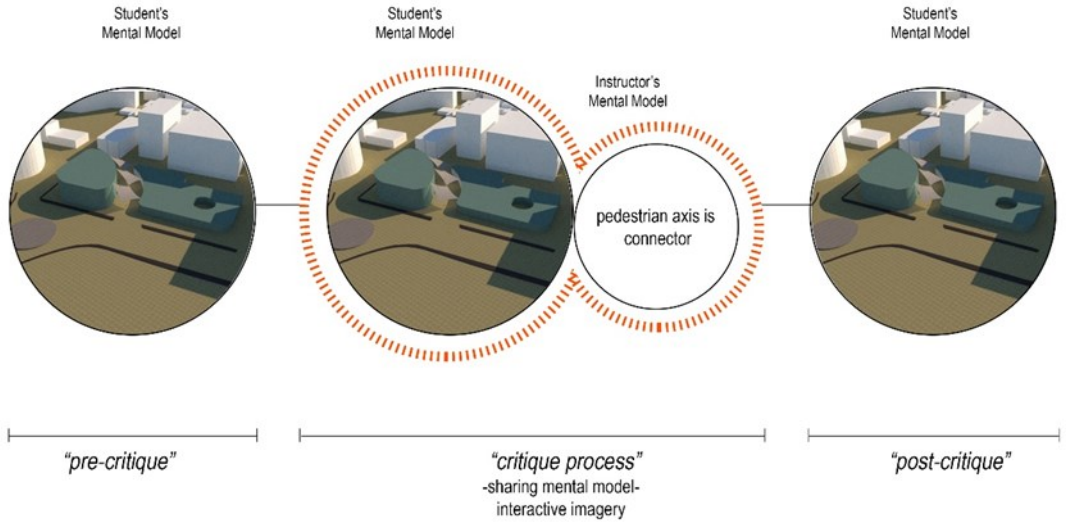


Figure 48: Step 1 of Case 3

Table 11: Step 1 of Case 3

Step1	**Type of Reasoning**	**Type of Transformation**
Student	x	x
Instructor 4	seeing as	x

Since the student refused to make any changes it is not possible to infer what he took from the critique. Instructor 4 offered that the connector idea should be reflected in the space organization. At this point, instructor's reasoning type can be interpreted as "seeing as" because she suggested a new conceptual proposal.

Step 2 – Desk Critique

Student presented the same material at the desk critique with Instructor 1 (Figure 39) and Instructor 1 suggested a metaphor (Figure 40) which triggered a significant change in student's understanding of the project. The process of the Step 2 (Figure 49) is summarized (Table 12) as follows:

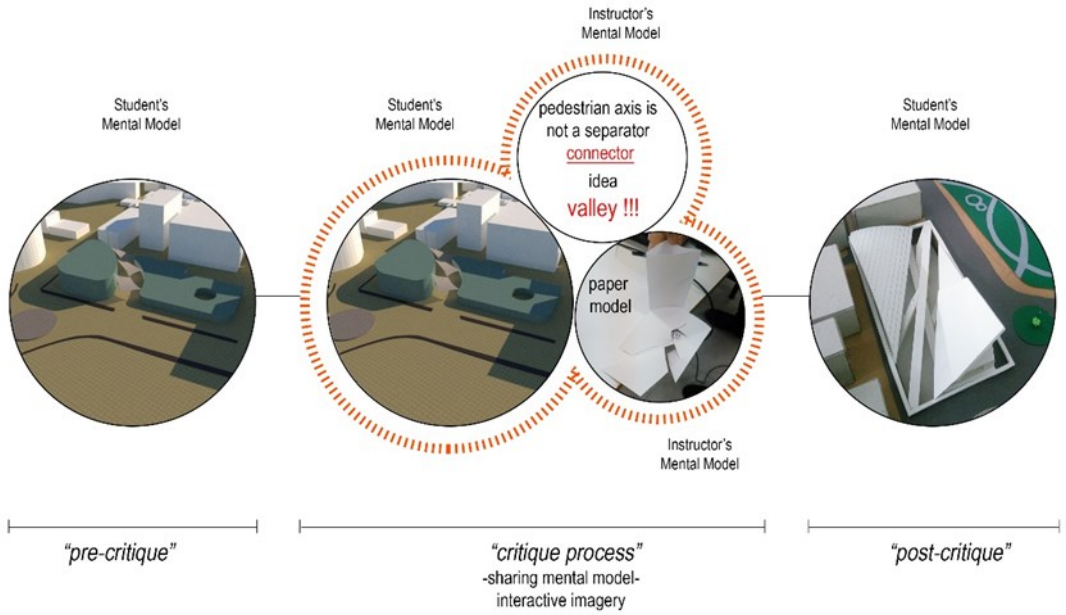


Figure 49: Step 2 of Case 3

Table 12: Step 2 of Case 3

Step 2	**Type of Reasoning**	**Type of Transformation**
Student	seeing that	lateral transformation
Instructor 1	seeing as	lateral transformation

The student focused on the valley metaphor from then on. The type of reasoning of the student in this process can be interpreted as "seeing that" because he made a new model by adding few things to the instructor's paper model but also, he kept the valley

idea. In addition to this, the shift can be interpreted as a “lateral transformation” because the valley metaphor changed the scheme drastically.

Instructor 1 saw a valley in the pedestrian axis and suggested a new conceptual approach. The type of reasoning of Instructor 1 in this process can be interpreted as “seeing as”. On the other hand, the change between the representation of Instructor 1 and the representation of the student can be interpreted as a “lateral transformation”. The reason for this is that the proposals are conceptually different from the representation of the student.

Instructor 1 presented the knowledge that will affect the conceptual development of the project. The student developed a new conceptual approach using this knowledge. For this reason, it is possible to interpret the learning style of the student at this step as “conceptual learning”.

Step 3 – Midterm Jury

The student presented his new scheme after the desk critique at the midterm jury (Figure 41). After the midterm jury, student tried to make some changes and he prepared a new scheme (Figure 43). The process of the student is summarized in Figure 50 and Table 13.

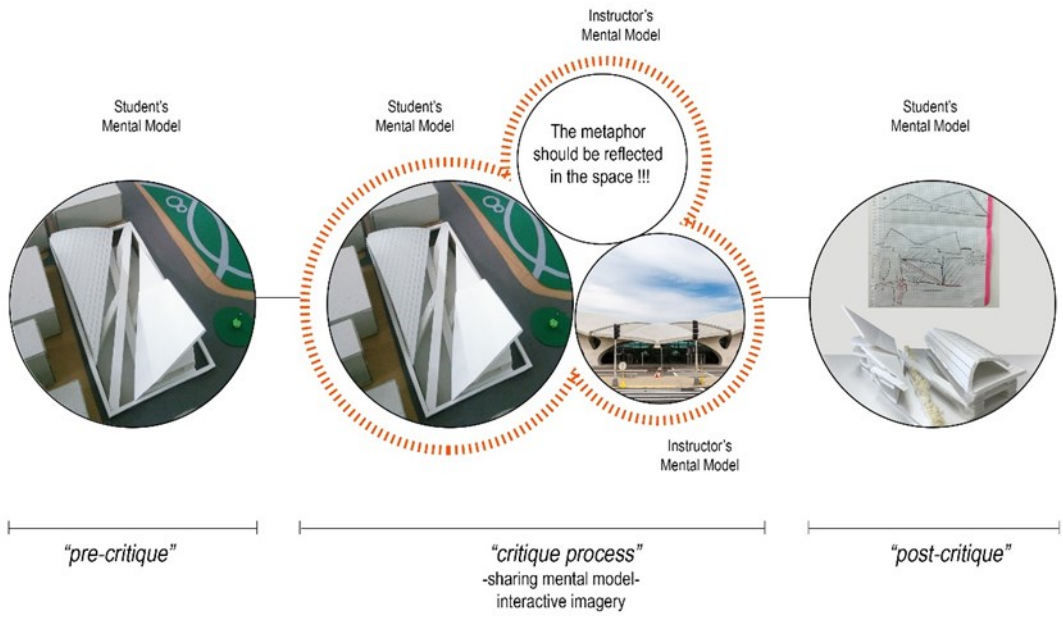


Figure 50: Step 3 of Case 3

Table 13: Step 3 of Case 3

Step 3	**Type of Reasoning**	**Type of Transformation**
Student	seeing that	vertical transformation
Instructor 2	seeing as	lateral transformation
Instructor 4	seeing that	x

The student tried to change the scheme because instructors did not like it. He thickened the pedestrian axis. He tried to change the slopes of the valley but he could not. He did not make conceptual changes. Therefore, the student's reasoning type can be interpreted as "seeing that". In addition, it is possible to interpret the transformation of student's scheme as "vertical transformation". The reason is that new representation did not trigger any conceptual changes.

Instructor 2 suggested that the valley idea should be considered only as a metaphor indicating that the slopes of the valley were like bird wings. Instructor 2's reasoning type can be interpreted as "seeing as" because he proposed a different point of view. On the other hand, the change between the example of Instructor 2 and the representation of the student can be interpreted as a "lateral transformation" because the example reflected conceptual differences.

Instructor 4 said that pedestrian axis was too thin. She questioned "why the pedestrian axis is diagonal". Instructor 4 suggested both spatial and technical ideas. At this point, instructor's reasoning type can be interpreted as "seeing that".

Instructor 2 presented conceptual knowledge and Instructor 4 presented both conceptual and procedural knowledge at the midterm jury. Student did not use any conceptual knowledge after the midterm jury. However, he used procedural knowledge and he changed the dimension of the pedestrian axis. For this reason, it is possible to interpret the learning style of the student at this step as "professional learning".

Step 4 – Desk Critique

Afterwards, the student presented his updated proposal at the desk critique with Instructor 3 (Figure 43). This step is summarized graphically (Figure 51) and in a table (Table 14) as follows:

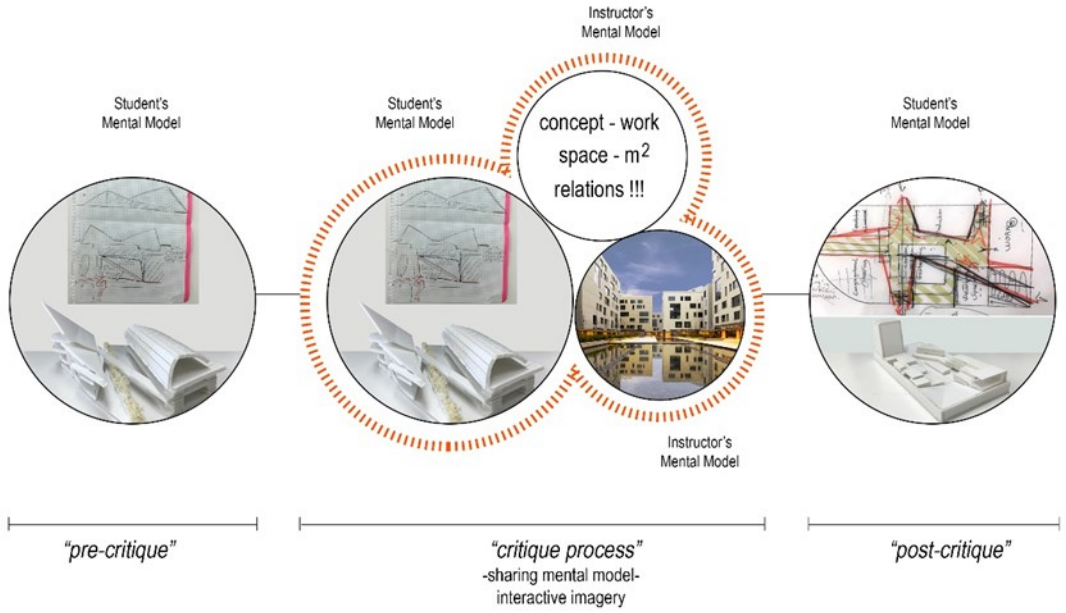


Figure 51: Step 4 of Case 3

Table 14: Step 4 of Case 3

Step 4	**Type of Reasoning**	**Type of Transformation**
Student	seeing that	lateral transformation
Instructor 3	seeing as	lateral transformation

He revisited the program and square meters at this stage. He decided to replace the slopes of valley with terraces created by mass organization. And then he made a new model. He placed a tower on one side of the model because of inadequate square meter. In other words, the student evaluated the project with a different mass organization. At this point, the student's reasoning type can be interpreted as "seeing that". He thought about a different mass organization with the new proposal by keeping the valley idea. Therefore, it is possible to interpret the representation transformation of student as a "lateral transformation".

Instructor 3 presented some conceptual knowledge during the desk critique. This knowledge was in relation to valley-work relation, work space-public space relation and square meter-space relation. Student used some of these and he prepared a new proposal after the desk critique. For this reason, it is possible to interpret the learning style of the student at this step as "conceptual learning".

Step 5 – Desk Critique

Finally, the student presented a final version of his scheme at the desk critique with Instructor 1 (Figure 45). The process of the student (Figure 52) is diagrammatically summarized (Table 15) as follows:

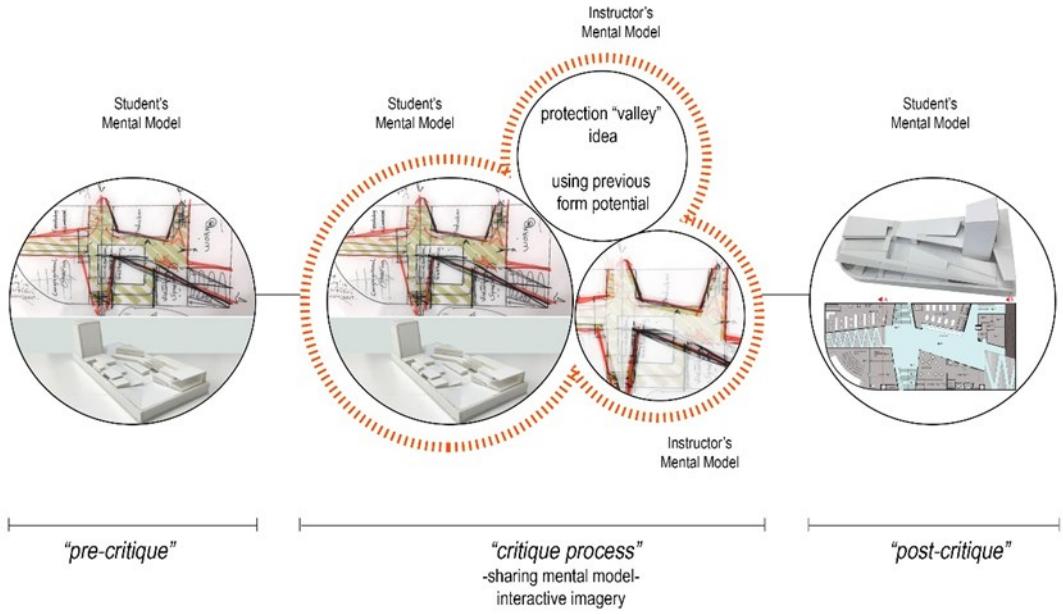


Figure 52: Step 5 of Case 3

Table 15: Step 5 of Case 3

Step 5	**Type of Reasoning**	**Type of Transformation**
Student	seeing that	lateral transformation
Instructor 1	seeing as	lateral transformation

Instructor 1 drew lines on student's sketch plan and the student copied these lines and made a new layout. At this point, student created a new proposal without any conceptual change on the instructor's proposal. Therefore, the type of reasoning of the student in this process can be interpreted as "seeing that". However, although the student did not add any changes, the new proposal had conceptual differences when compared to his earlier scheme because it was a copy of the instructor's proposal. There were conceptual differences between pre-critique proposal and post-critique of student. In the post-critique proposal, he used a shell to create topography. For this reason, it is possible to interpret the representational transformation as a "lateral transformation".

Instructor 1 mentioned that the previous form had more potential. He said that the valley metaphor should be reconsidered. He suggested topography as a way of thinking about the valley metaphor could help. At this point, the instructor's reasoning type can be interpreted as "seeing as" because he suggested conceptual changes. In addition to this, he reflected these ideas on the sketch. Thus, it is possible to interpret the representation transformation of instructor as "lateral transformation".

Instructor 1 presented conceptual knowledge at the desk critique. The student used it directly. In other words, he used it by copying instructor's proposal. For this reason, it is possible to interpret the learning style of the student at this step as "conceptual learning".

4.3.3. Discussion

In this section Case 3 is discussed in terms of cognitive components of design, i.e., representation and reasoning.

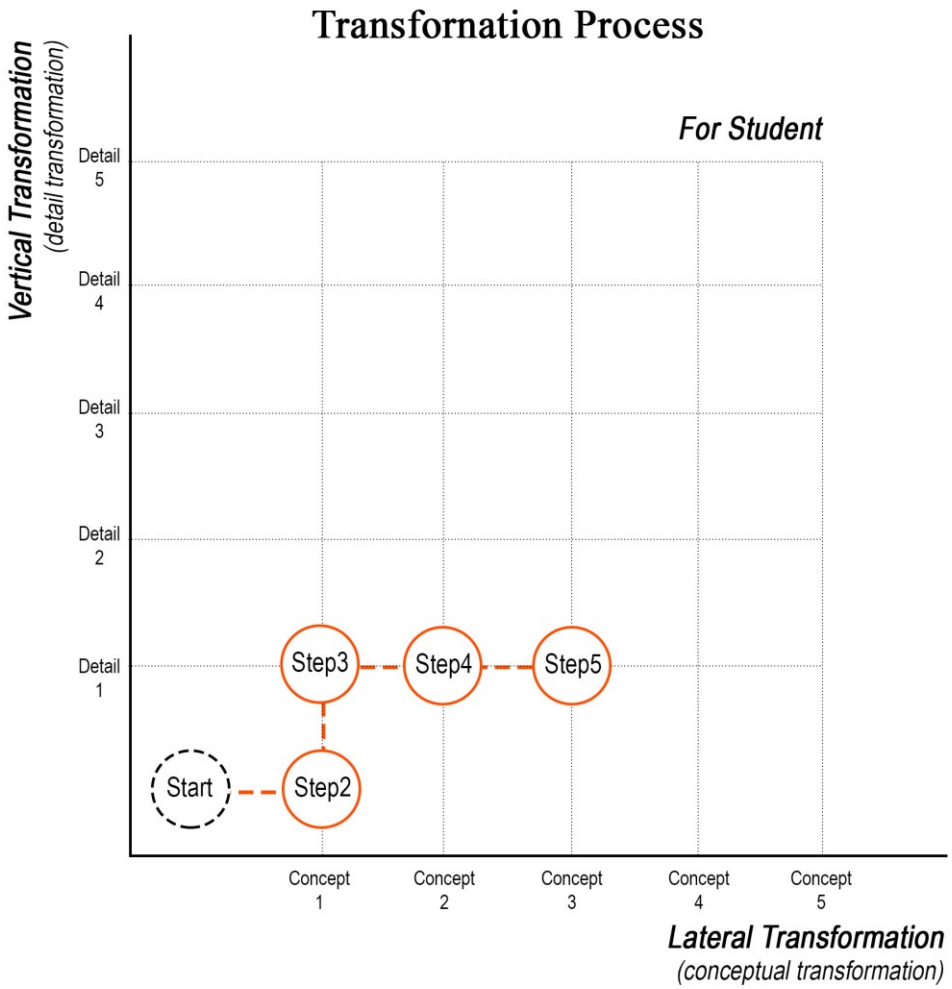
Representation

In this case, the student achieved a final product mostly with lateral transformations (in Step 2, Step 4, and Step 5) in the project development process (Figure 53). It is possible to say that the student produced a new scheme mostly with conceptual shifts from the knowledge which was obtained from critiques and juries. In terms of instructors, all of them used lateral transformation at all of steps.

Reasoning

Pictorial reasoning is "seeing that" at all steps (Figure 53). In terms of instructors, almost all of them used "seeing as" at all steps. It is possible to say that the student did not add any interpretations on instructors' proposals which were given at the critiques.

Briefly, in this case, the student began the project with "creating a pedestrian axis" but he continued with a different concept. This concept emerged from the valley metaphor which was proposed by Instructor 1. During the conceptual development process of his project, he could not reflect properly on the metaphor. Sometimes the student copied some proposals which were made by instructors.



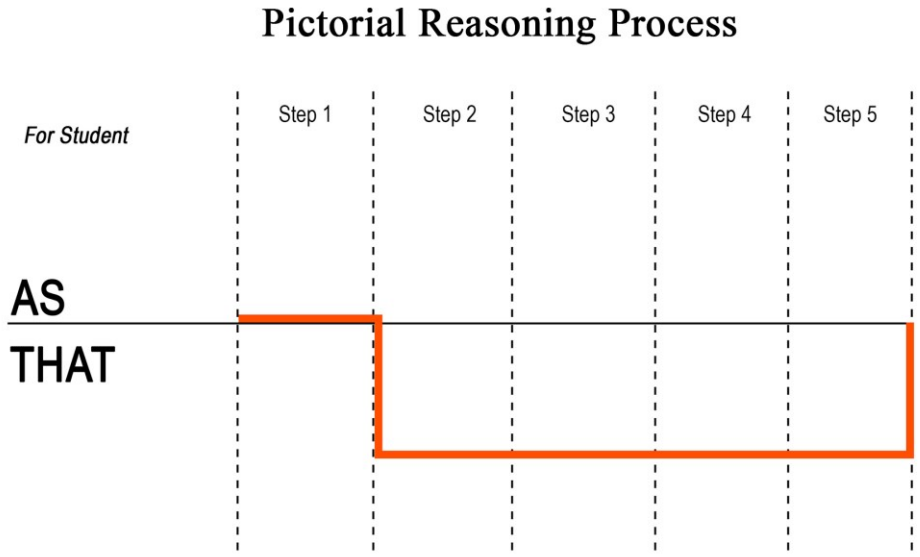


Figure 53: Transformation Process and Pictorial Reasoning Process of Case 3

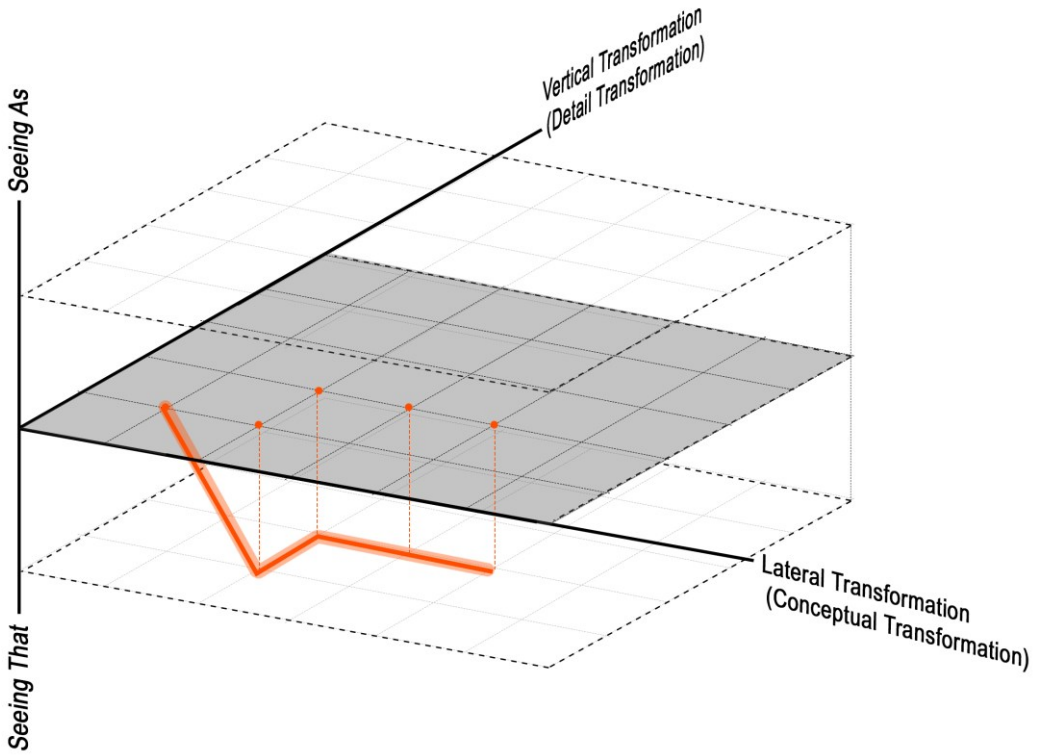


Figure 54: Design Path of Case 3

It is possible to interpret that student took into consideration instructors' proposals and he tried to use it (Figure 54). Perhaps, at the beginning of the project process, he did not have the knowledge or ability to represent these changes. However, during desk critiques, jury, and panel review, he conceptually developed his project through trying to apply instructors' proposal.

4.4. Case 4 - Student 4

Student 4 adopted a "struggler" attitude in her project process. She conserved her initial concept until the end of her project. She made efforts to reflect the concept to the project. She took into consideration the instructors' suggestions during the project development process. Although Student 4 was not very successful while adapting instructors' suggestions to the project, she was eager to develop the project.

4.4.1. Process

The student proposed to work with a design concept, i.e., “cross pollination”, at the very beginning of the semester. She explained:

> At the beginning of the project, I searched on work and productivity. I read many articles related to these topics. I encountered the notion of "cross pollination" in one of the articles. Actually, the term is a biologic term, but it has a relationship with work and productivity. The concept suggests that the more randomly people encounter each other at work, the more productive they become. This idea influenced me. Then I decided to use this term in my project. I proposed randomly arranged spaces to increase the probability of encounters among people. Therefore, I tried to put together different program spaces.

The student represented her initial thoughts in a series of drawings (Figure 55) and presented these at the first panel review. One of the instructors gave Herman Hertzberger’s *Centraal Beheer* as a precedent (Figure 56) that she can analyze to understand the relationship between work and socialization. She reported “Instructors liked [her] concept and they suggested a metaphor which was related space organization.”

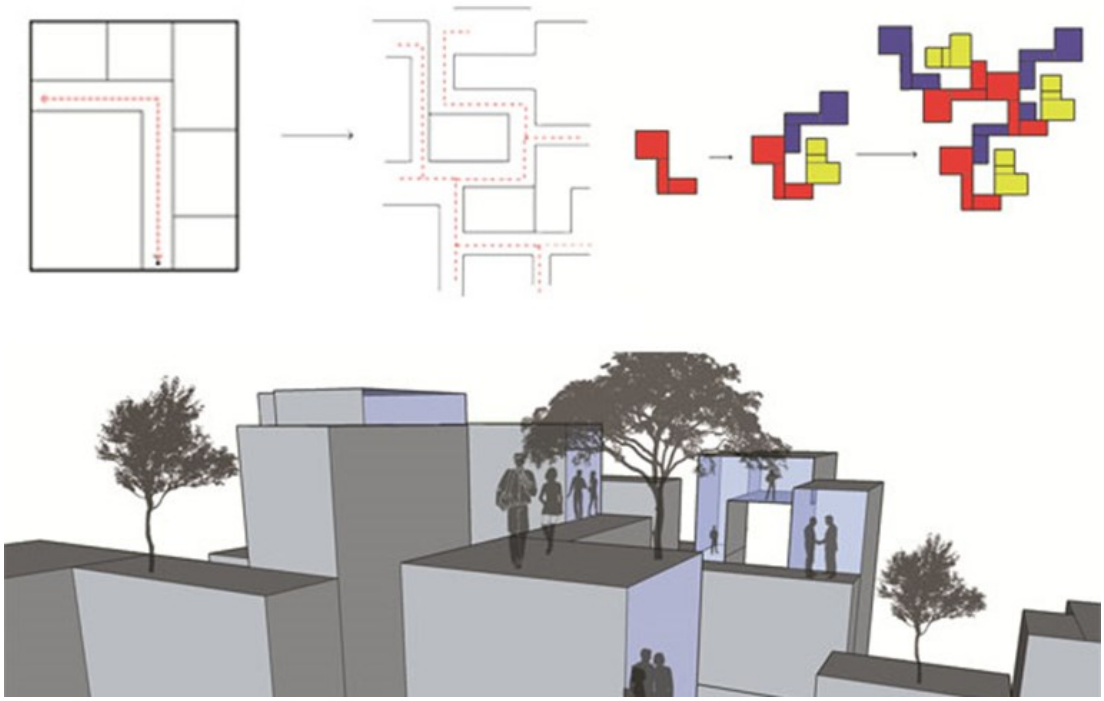


Figure 55: Representations of Student 4

Instructor 1 explained his ideas at the panel review as follows:

> Student's idea was interesting but there were deficiencies in the spatialization of the concept. I suggested her to think with a metaphor at the panel review expanding student's metaphor of cross-pollination by way of introducing the "workspace-beehive" and "productive space-flowers" analogies.

Instructor 2 added that:

> I talked about the characteristics of the spaces that people interact with each other. Also I gave the of example Centraal Beheer by Herman Hertzberger as a precedent. I explained how the modules come together to create a social space. I mentioned that it is necessary to arrange spaces from this point of view and I suggested to her to use the free plan that will fit her concept better.

Figure 56: Centraal Beheer by Herman Hertzberger
(Source: The Architectural Review website, 2018)

Instructor 4 stated:

> I think her scenario was good. Instructors liked it. However, the student was not aware of the metaphor. I suggested that the metaphor needed to lead the spatial organization.

After the panel review, the student changed her scheme and presented this at the desk critique with Instructor 1 (Figure 57). Instructor 1 suggested some ideas and he made sketches to explain his idea (Figure 58). In the interview, student explained Instructor's comments as follows:

> After the panel review, I made a sketch to rethink the suggestions offered at the panel review. I randomly placed different program spaces. I called productive spaces as "node". Instructor 1 commented on this sketch and he further explained the metaphor of cross-pollination. He explained to me how to design a space following this concept. Then he made sketches to show it. Also, he stated that nodes should be spaces, it should not be platforms.

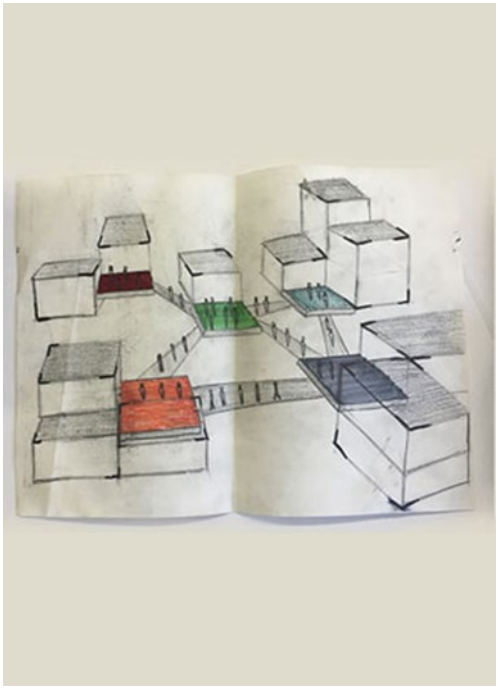


Figure 57: Sketch of Student 4

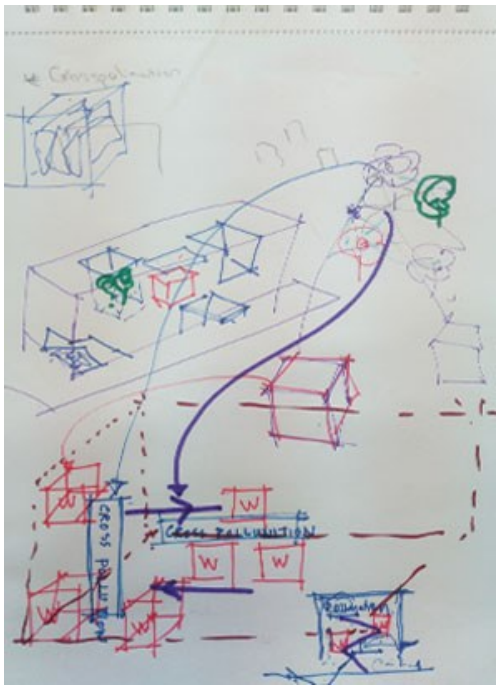


Figure 58: Sketch of Instructor 1

Instructor 1 corroborated the student's account in these words:

> Firstly, I explained the metaphor and the concept. I tried to explain what kind of spaces the metaphor entails. Also, I made a sketch. I emphasized that nodes should be spaces with different characters. I also mentioned that there should be a circulation system among the nodes.

After desk critique, student modified her scheme (Figure 59) through diagrams, plan, and section drawings, and a model. In the new scheme, she added a thin skin all around the nodes and platforms to emphasize the idea of a beehive. She presented these at the midterm jury, which she remembered along these lines:

> After the desk critique, I studied further on the metaphor. I wanted to spatialize the metaphor. Then, I designed a circulation among the nodes. I placed the nodes at different levels and I added different programs to them. Also, I designed a shell to create a space for nodes.

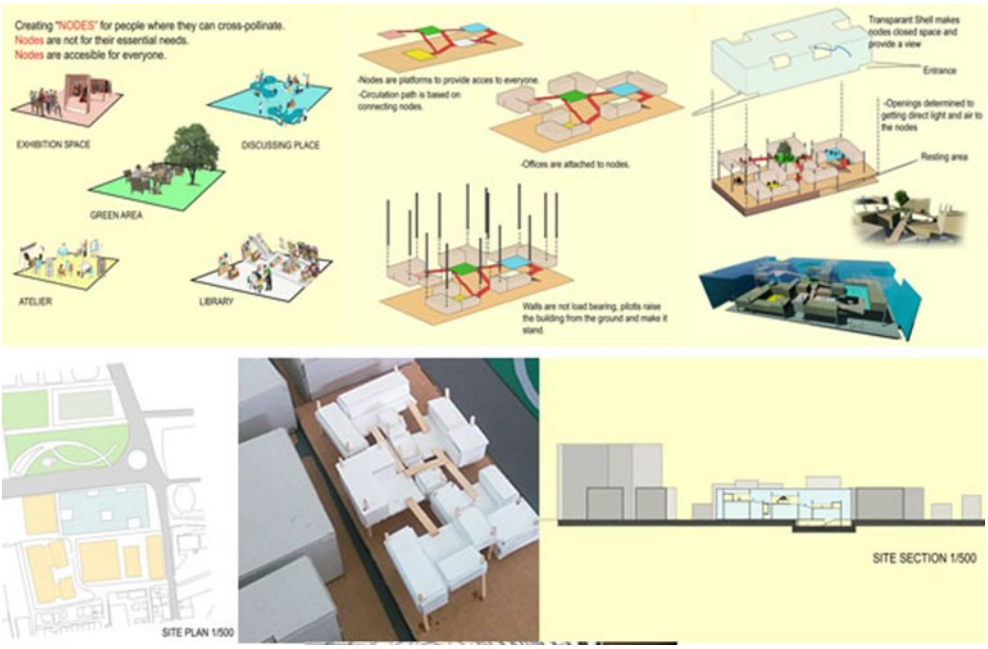


Figure 59: Midterm representations of Student 4

At the midterm review, Instructor 2 gave an example, *DZ Bank Building* by Frank Gehry, as a precedent (Figure 60). The student remembered the instructors' comments like this:

> Instructors criticized the shell. They said the shell should be different. Also, they indicated that the metaphor should be reflected more strongly in the spatial organization. One of instructors gave an example.

Instructor 1 remembered the midterm jury as follows:

> I emphasized that nodes should be spaces in different characters. I stated that it is not necessary to gather all spaces under a single shell. Also, I said that metaphor should be reflected in the spatial organization.

Instructor 2 stated that:

> I did not like shell form. I think it looked like a block of cheese. I think the student understood that a different shell was needed but she had no idea. Therefore, I gave the example of DZ Bank Building by Frank Gehry as a precedent. This example was about different space organizations also it was concerned with both spatial organization and form.

After the midterm jury, the student made a new digital model (Figure 61) trying to come up with a more dynamic shell, or in her words with "a different shell". She presented it at the desk critique with Instructor 2. Instructor 2 suggested some ideas and he made a sketch (Figure 62). Instructor 2, however, focused mainly on the circulation system within the building that will unify the atomized module and explained his ideas at the desk critique as follows:

> The student designed a different shell after the midterm jury. I suggested a different spatial organization because she did not have an idea about space organization. I told her to work on the circulation among the nodes. I emphasized that this circulation should be an alternative circulation which was independent of the main circulation. Then, I made a sketch section to explain my ideas.

After the desk critique, student made a new digital model and model (Figure 63), in which she had abandoned the idea of wrapping all the nodes and platforms with a shell. She explained the reason as follows:

> At the desk critique, the Instructor described an alternative spatial organization. Firstly, I rethought the shell. Then, I removed the shell to change the massing because the instructors did not like it at the midterm jury. In addition, I changed the dimensions of the nodes.

Student presented these representations at the desk critique with Instructor 1 (Figure 63). Instructor 1 reminded her of the significance of the metaphor and he explained his ideas with a sketch drawn on a student's section drawing (Figure 64). He explained his ideas at the desk critique as follows:

> I re-explained the metaphor because she had forgotten its main significance. The shell idea had disappeared. I reminded her all of these concepts again. I suggested that the metaphor-space relation should be reflected in the project and especially in the shell design. I proposed to differentiate the shell by moving it back and forth. In addition, I explained these ideas with a sketch.

After the desk critique, the student made a new digital model, plan, and section drawings (Figure 65) by reintroducing the shell as a main component in the massing.

Figure 60: DZ Bank Building by Frank Gehry
(Source: ArchDaily website, 2018)

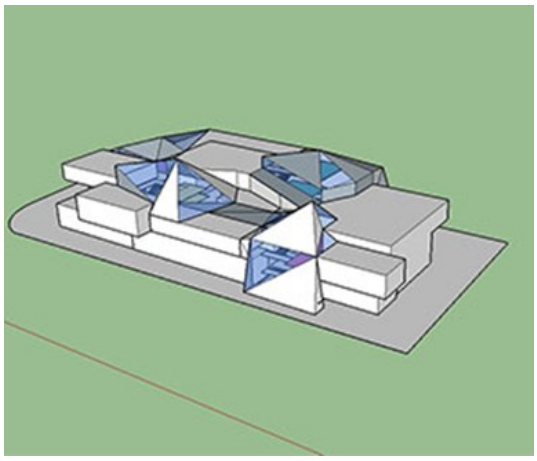


Figure 61: Digital model of Student 4

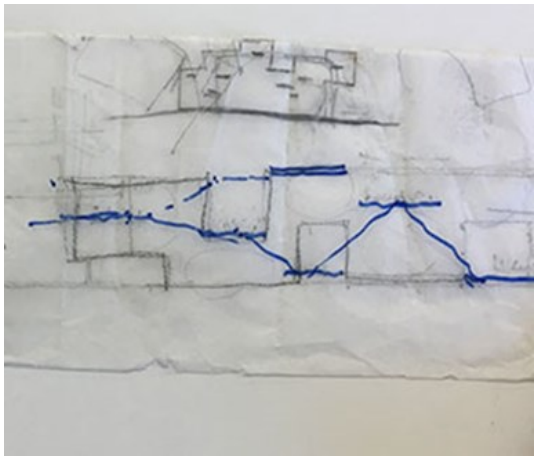


Figure 62: Sketch of Instructor 2

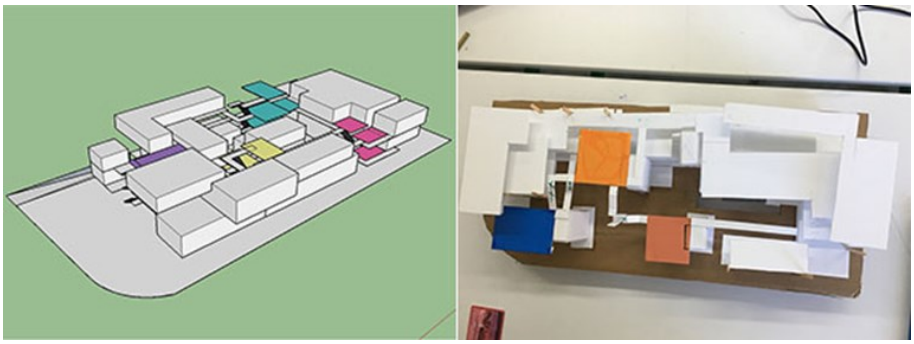


Figure 63: Digital model and model of Student 4

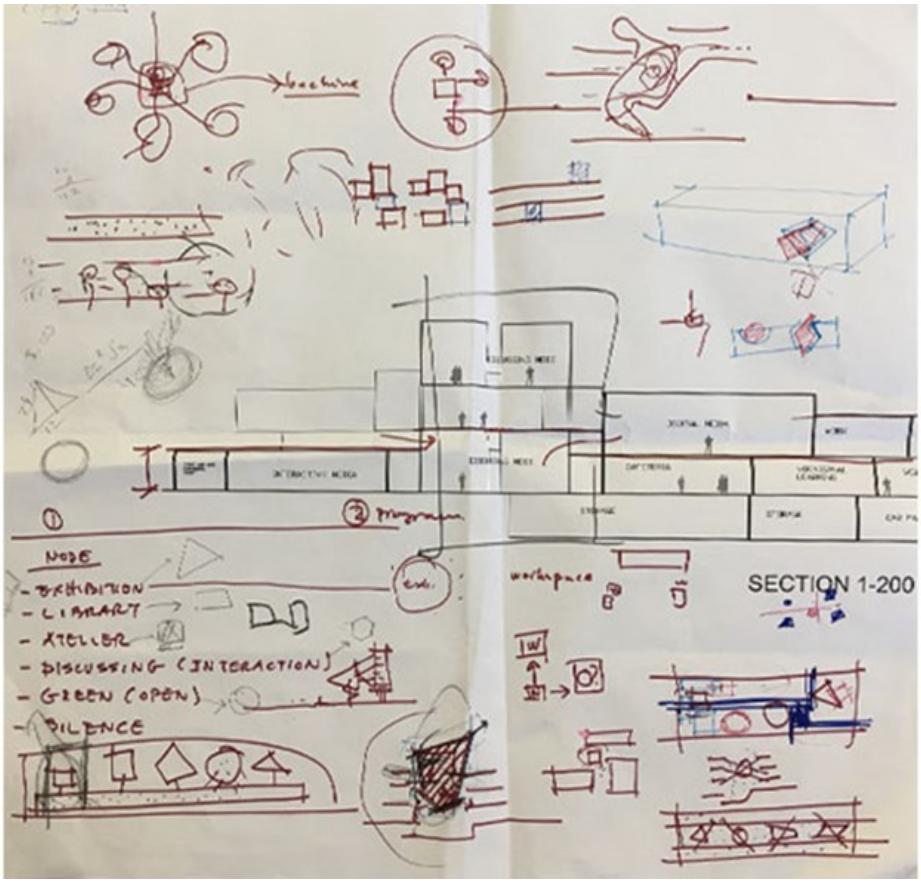


Figure 64: Proposals of Instructor 1

Thus, the student completed the conceptual development process of her project. She related the following with the regards to the last scheme:

> After the desk critique, I designed a new shell. I designed different facades through moving the shell back and forth. I placed some programs at the upper floors, which increased the building height. I think the latest scheme was good. I really liked it. In addition, I really worked hard during the process.

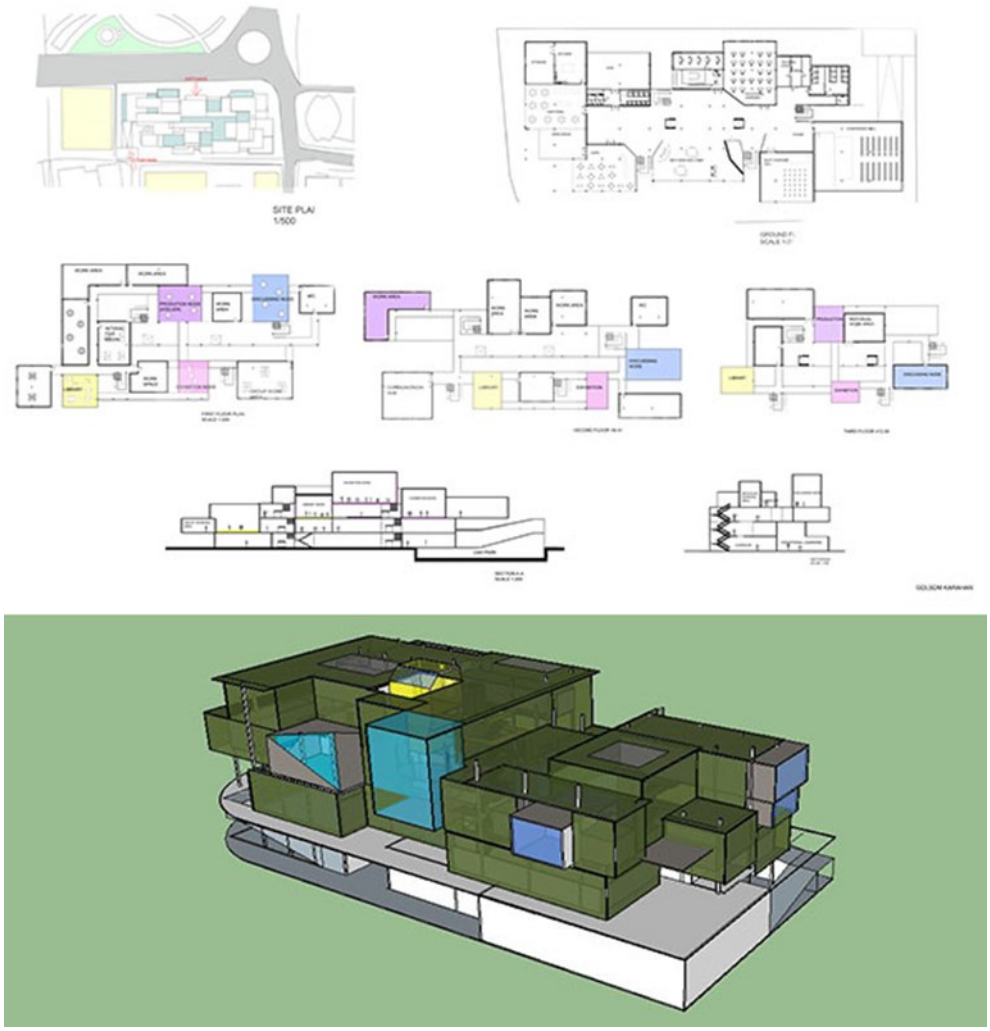


Figure 65: Representations of Student 4

Instructor 1, in contrast to student's perception, thought "she could not reflect the metaphor in the spatial organization. Last phase of the project was not too bad but it was not very good either."

Instructor 2 agreed with Instructor 1 that the metaphor was not adequately leading the spatial organization and added that "the student worked hard, really trying to do something. However, she had difficulty in moving forward." Instructor 3, to whom the student did not consult at all during this process, "liked her concept", however, that "the form was not as good as the concept.

Instructor 4 added:

> I think her scenario was good. However, when the concept became a project, it did not turned to be a very good project. I think the student could not understand the metaphor.

4.4.2. Interpretation

In this section, the conceptual design phase of the student's project is examined in five steps: Step 1 - Panel Review, Step 2 – Desk Critique with Instructor 1, Step 3 – Midterm Jury, Step 4 – Desk Critique with Instructor 2, and Step 5 – Desk Critique with Instructor 1.

Step 1 – Panel Review

The student presented the cross pollination idea and related material at panel review (Figure 55). After the panel review, the student prepared a new set of representations (Figure 57). The process of the student is summarized graphically (Figure 66) and analyzed in terms of reasoning strategies and type of transformations (Table 16) as follows:

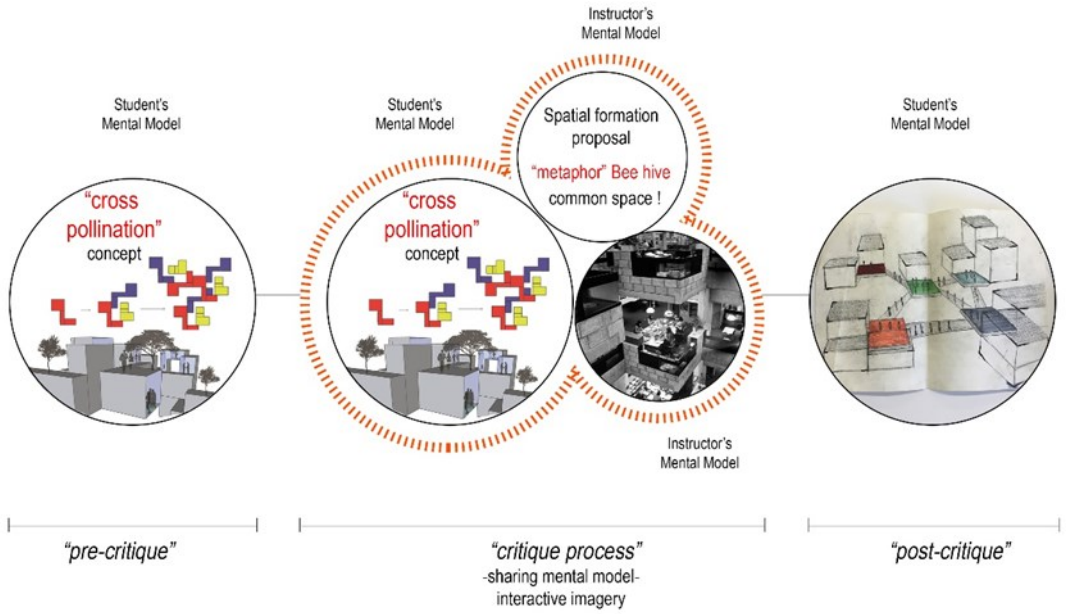


Figure 66: Step 1 of Case 4

Table 16: Step 1 of Case 4

Step1	**Type of Reasoning**	**Type of Transformation**
Student	seeing that	vertical transformation
Instructor 1	seeing as	x
Instructor 2	seeing as	lateral transformation
Instructor 4	seeing as	x

There was no direct indication of a metaphor use in the representations, which the student prepared for the panel review, but the idea of cross-pollination hinted a metaphor. She thought that to increase encounters and productivity spaces needed to be organized randomly. At the panel review, instructors converted the cross-pollination into a metaphor with specific analogies to a beehive and bees buzzing between flowers. The student created a new scheme after these suggestions. She did not fully reflect the metaphor on the project. A new sketch drawn by student looked like a diagram drawn at the panel review. Therefore, the type of reasoning of the student in this process can be interpreted as "seeing that". It is possible to interpret the representational change as a "vertical transformation" because the new scheme did introduce a conceptually new idea.

Instructor 1 suggested the beehive metaphor, based on the idea of cross-pollination, highlighting the notions of "workspace-beehive" and "productive space-flowers". In other words, he suggested a conceptual change. At this point, Instructor 1's reasoning type can be interpreted as "seeing as". Instructor 2 gave the example of *Centraal Beheer* by Herman Hertzberger as a precedent. He explained how the modules come together to create a social space. He mentioned that it is necessary to arrange the spaces from this point of view and he suggested her to follow the principles of free plan to better reflect the concept. These suggestions resulted in a conceptual change. Therefore, the type of reasoning of the Instructor 2 in this process can be interpreted as "seeing as". On the other hand, the example presented by Instructor 2 reflects a conceptual change. The change between the representation of Instructor 1 and the representation of the student can be interpreted as a "lateral transformation".

Instructor 1, Instructor 2, and Instructor 4 offered different sets of conceptual knowledge with the aim of triggering a conceptual shift in student's mental representation. However, the student did not use this knowledge in the new set of representations. Therefore, her learning process cannot be interpreted at this step.

Step 2 – Desk Critique

After the panel review, the student presented her new scheme (Figure 57) at the desk critique with Instructor 1 which led to a new set representations presented at the midterm jury (Figure 59). The process of the Step 2 (Figure 67) is summarized (Table 17) as follows:

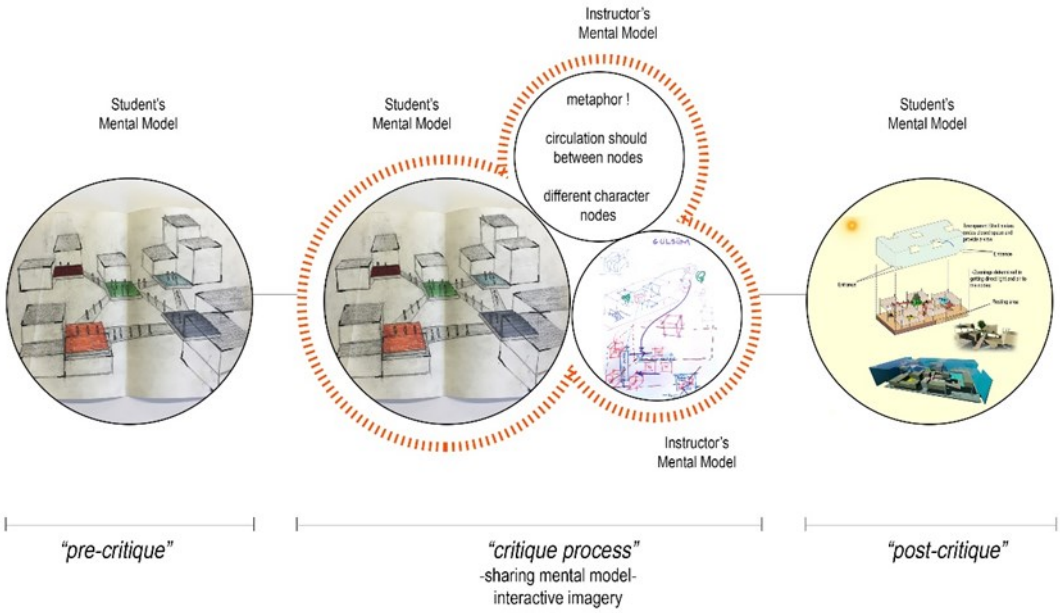


Figure 67: Step 2 of Case 4

Table 17: Step 2 of Case 4

Step 2	**Type of Reasoning**	**Type of Transformation**
Student	seeing as	lateral transformation
Instructor 1	seeing as	lateral transformation

After the desk critique, the student worked on the metaphor. She created a new set of representations to reflect on the spatial implications of the metaphor. She designed a circulation system between nodes and created a shell to wrap all the individual masses. In other words, student changed her project based on the conceptual suggestions. For these reason, the student's reasoning in this process can be interpreted as "seeing as". In addition, the representational transformation can be interpreted as a "lateral transformation" because she reflected conceptual changes to the representations.

Instructor 1 explained the details of the metaphor during the desk critique. He tried to explain how metaphor needed to be reflected in the spatial organization. He emphasized that nodes should be spaces in different characters. He also mentioned that there should be a circulation among the nodes. At this point, the instructor's reasoning type can be interpreted as "seeing as" because he suggested a conceptual change while his representational transformation can be interpreted as "lateral transformation".

Instructor 1 suggested conceptual knowledge at the desk critique which resulted in a conceptual change. Therefore, it is possible to interpret the learning style of the student at this step as "conceptual learning".

Step 3 – Midterm Jury

After the desk critique, student presented her new set of representations (Figure 59) at the midterm jury. Instructor 2 gave an example *DZ Bank Building* by Frank Gehry as a precedent (Figure 60). The student prepared a new digital model after the midterm jury (Figure 61). The process of the student is summarized in Figure 68 and Table 18.

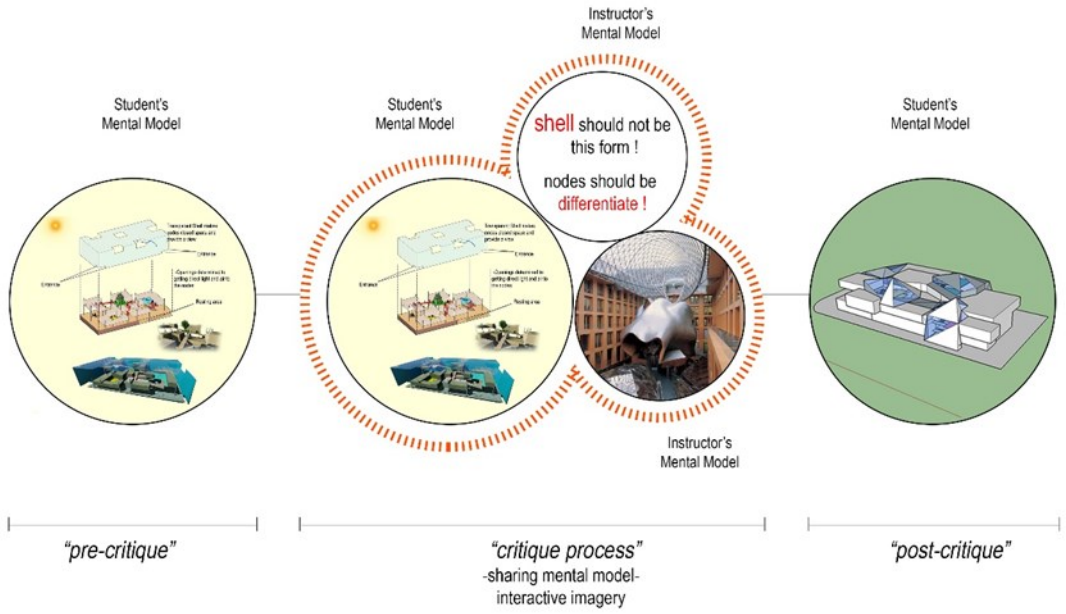


Figure 68: Step 3 of Case 4

Table 18: Step 3 of Case 4

Step 3	**Type of Reasoning**	**Type of Transformation**
Student	seeing that	vertical transformation
Instructor 1	seeing as	x
Instructor 2	seeing as	lateral transformation

Instructors' suggestions ranged from node-shell relation, metaphor-space relation, to spatial organization. However, the student only changed the form of the shell after the midterm jury. At this point, student's reasoning type can be interpreted as "seeing that" because student did not make any conceptual changes. The only changes

she made were detail related changes. She reflected these detail changes on the digital model. Therefore, the student's representation change can be interpreted as a “vertical transformation”.

Instructor 1 suggested new conceptual ideas. He emphasized that nodes should be spaces in different characters. He stated that it is not necessary to gather all the spaces under a single shell. In addition, he said that the metaphor should be instrumental in organizing the spaces. Therefore, Instructor’s reasoning type can be interpreted as “seeing as”. Instructor 2 suggested ideas about the shell form and spatial organization. He gave an example to illustrate different space organizations. For this reason, Instructor’s reasoning type can be interpreted as “seeing as”. In addition, his example reflected conceptual ideas so, the change between the representation of Instructor 2 and the representation of the student can be interpreted as a “lateral transformation”.

Instructor 1 and Instructor 2 suggested conceptual knowledge. However, student did not use this knowledge in the new set of representation. Therefore, her learning process cannot be interpreted at this step.

Step 4 – Desk Critique

After the midterm jury, the student presented her modified scheme at the desk critique with Instructor 2 (Figure 61) which was further modified after the critique (Figure 63). This step is summarized graphically (Figure 69) and in a table (Table19) as follows:

Instructor 2 suggested a new spatial organization and circulation system. However, student did not use these suggestions. The student removed the shell to change it and she changed the dimensions of the nodes. In other words, she did not make any conceptual changes. Therefore, the type of reasoning of the student in this process can be interpreted as “seeing that”. It is possible to interpret the representational transformation of student as a “vertical transformation”.

Instructor 2 suggested an alternative spatial organization. He told her to edit the circulation among the nodes. He emphasized that this circulation should be an alternative circulation, which was independent of the main circulation. Instructor 2’s reasoning type can be interpreted as “seeing as” because he suggested conceptual

changes. Also, it is possible to interpret the representational transformation of the instructor as a "lateral transformation".

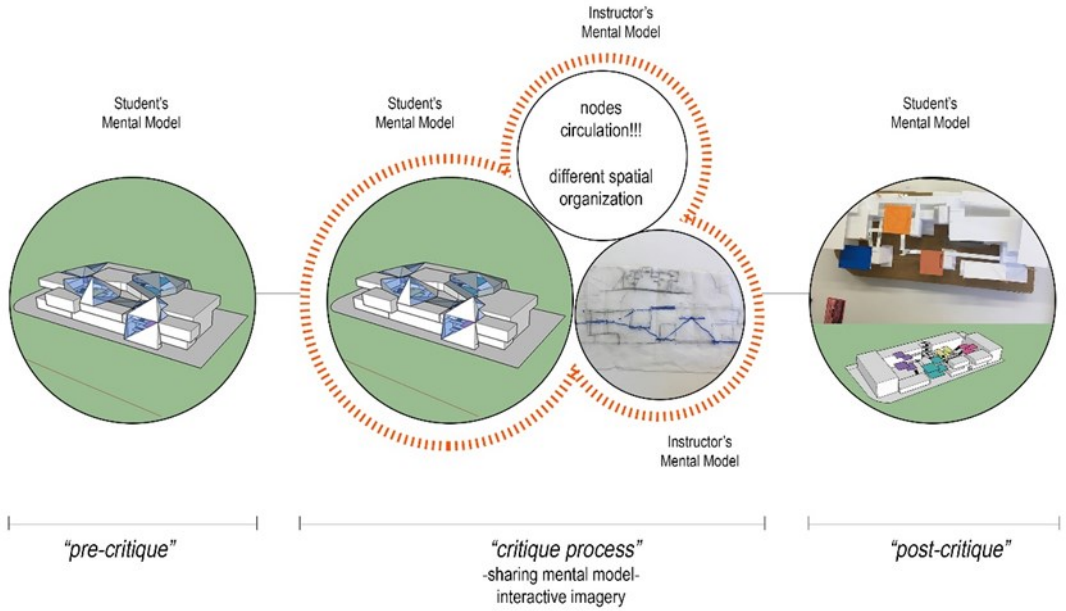


Figure 69: Step 4 of Case 4

Table 19: Step 4 of Case 4

Step 4	**Type of Reasoning**	**Type of Transformation**
Student	seeing that	vertical transformation
Instructor 2	seeing as	lateral transformation

Instructor 2 suggested conceptual knowledge at the desk critique. However, student did not use this knowledge in the new set of representations. Therefore, her learning process cannot be interpreted in this step.

Step 5 – Desk Critique

The student presented a digital model and a model (Figure 62) at the desk critique with Instructor 1. Instructor 1 reminded her the metaphor (Figure 63). After the desk critique, the student prepared a new set of representations (Figure 64) and thus the student completed the conceptual development. The process of the student (Figure 70) is diagrammatically summarized (Table 20) as follows:

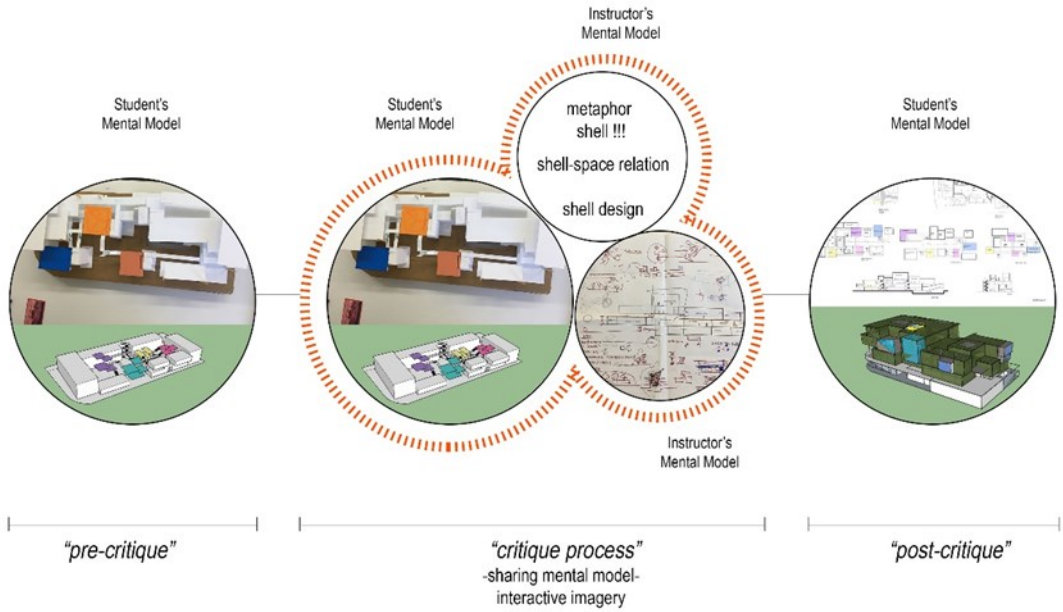


Figure 70: Step 5 of Case 4

Table 20: Step 5 of Case 4

Step 5	**Type of Reasoning**	**Type of Transformation**
Student	seeing that	vertical transformation
Instructor 1	seeing as	lateral transformation

Despite the fact that Instructor 1 reminded the metaphor, the student did not make any changes to the spatial organization. She designed a new shell and designed a different facade by moving the shell back and forth. She placed some programs at the upper floor which increased the building height. At this step, the student did not make any conceptual changes, she made only detail changes. Therefore, student's reasoning type can be interpreted "seeing that". In addition to this, it is possible to interpret the representation transformation of student as "vertical transformation" because there are only detail changes.

Instructor 1 explained the metaphor again because student seemed to forget it. He suggested that the metaphor-space relation should be reflected in the project and the shell design. He proposed to differentiate the facade by moving the shell back and forth. At this point, Instructor 1's reasoning type can be interpreted as "seeing as" because he suggested conceptual changes. Also, it is possible to interpret the representation transformation of Instructor as "lateral transformation" because he reflected conceptual ideas to section.

Instructor 2 suggested conceptual knowledge in the desk critique. However, student used only one of them which were different shell design. Therefore, in this step, student's learning type can be interpreted as "conceptual learning".

4.4.3. Discussion

Representation

In this case, the student's design path has different transformation process and pictorial reasoning process (Figure 71). The student achieved a final scheme mostly with "vertical transformations" (in Step 1, Step 3, Step 4, and Step 5) (Figure 72). At this point, it is possible to say that the student produced a new scheme mostly with changes concerning detailing. In terms of instructors, all of them used "lateral transformation" at all steps.

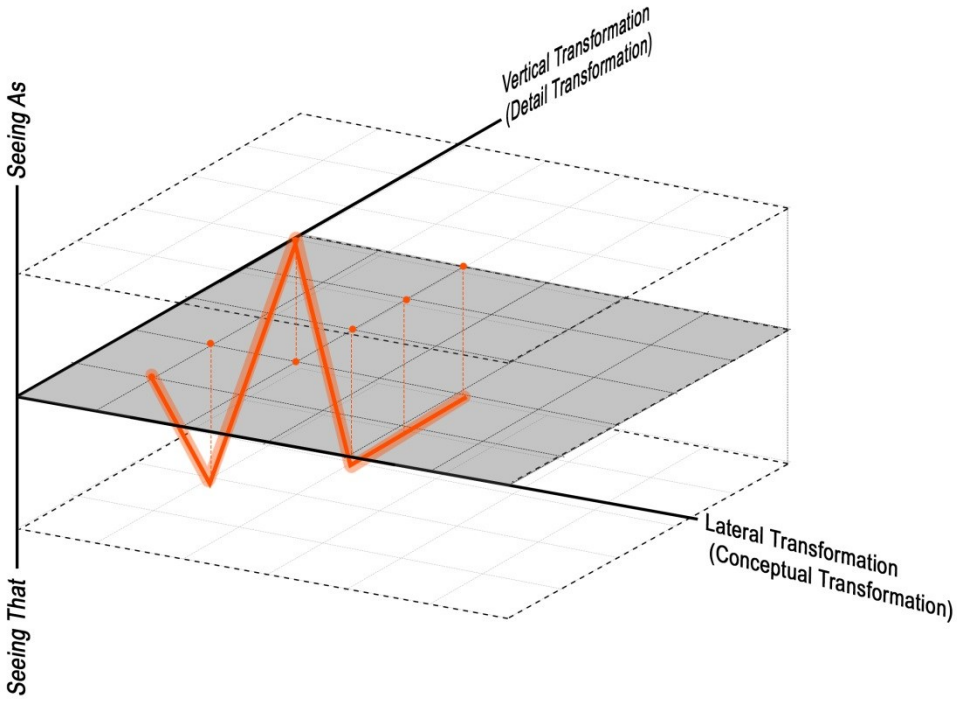
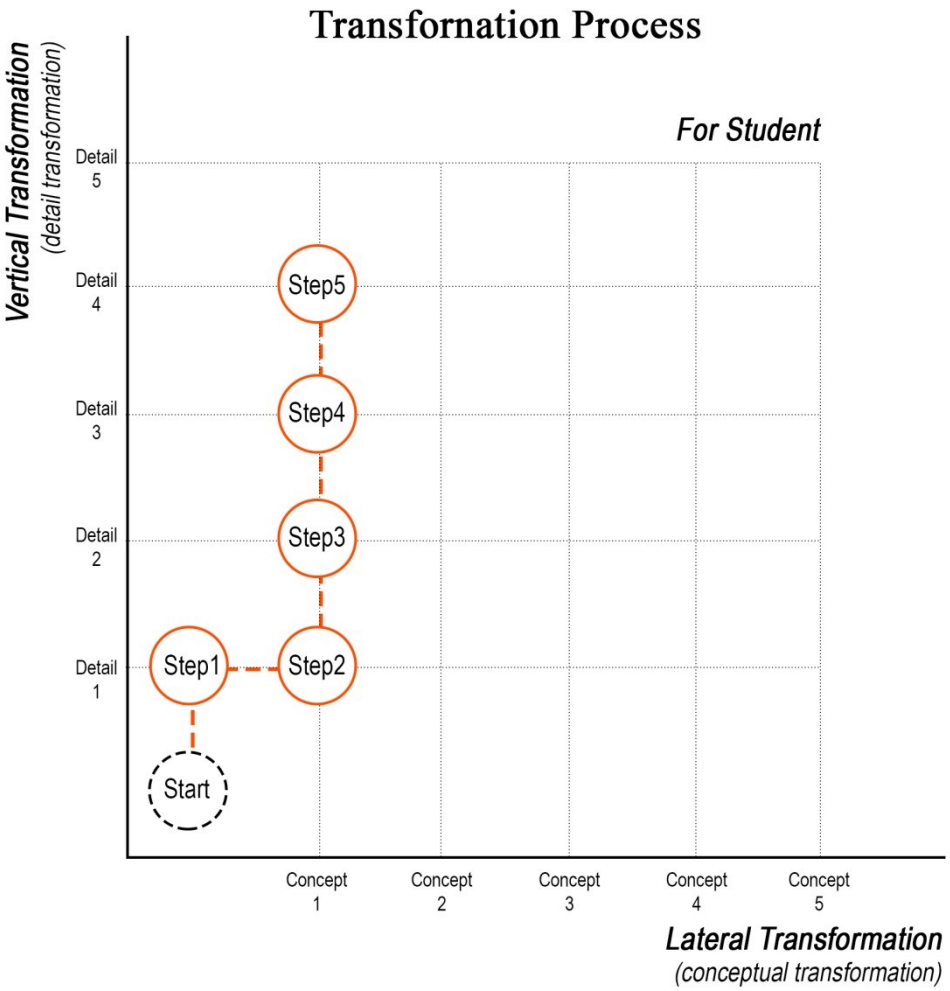


Figure 71: Design Path of Case 4

Reasoning

The student created a new scheme with conceptual knowledge during the reasoning process. In the project process of this student, pictorial reasoning is mostly "seeing that" (in Step 1, Step 3, Step 4, and Step 5) (Figure 72).



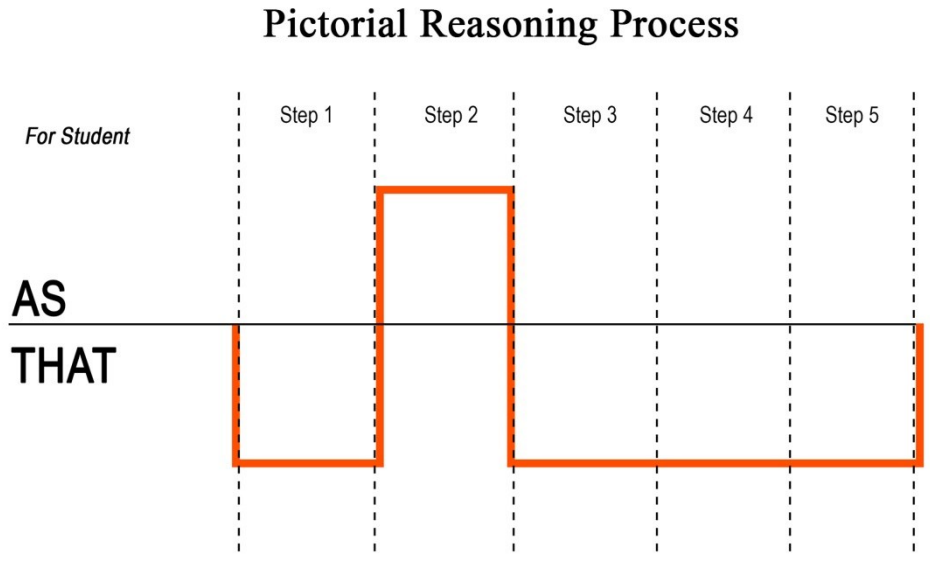


Figure 72: Transformation Process and Pictorial Reasoning Process of Case 4

At this point, it is possible to state that the student could not add new conceptual approaches to her scheme after desk critique or juries. In terms of instructors, all of them used “seeing as” at all steps.

Briefly, the student began the project with a concept. During the conceptual development process of her project, she could not adequately reflect her concept and metaphor in her project. Instructors proposed different perspectives to develop her project at the jury, panel review and desk critiques. However, the student could not grasp the different perspectives. Thus, she developed her project with detail changes.

4.5. Results and Discussion

In this study, four cases were discussed and analyzed. In each case, conceptual development process of students’ projects were analyzed in terms of visual reasoning strategies, i.e., “seeing as” and “seeing that”, used by instructors and students and of shifts in design ideas, i.e., lateral and vertical transformations. When four cases are compared, it is possible to say that each case illustrates a different process.

Both students and instructors during the interactive imagery sessions of design critiques created new images with externalized mental models through external representations facilitated by interactions between different media, the instructors, and the students. According to Goldschmidt (2001), images that have never been perceived before can occur through imagery. In this process, the designer works like an inventor to discover something new based on "existing things in mind". Every development or metamorphosis that takes place in this process is evidence of one new knowledge and thinking action (Goel 1995). According to Goldschmidt (1991), imagery is the essence of seeing something as something else. If this happens in the sketch process or external representation process, it is “interactive imagery” in words of Goldschmidt (Goldschmidt 1991, 131). The interactive imagery allows the designer to communicate with the materials (Goldschmidt 2001). During the design process, there are stimuli that evoke visual image or conceptual knowledge from memory and make them active in memory (Figure 2). The stimuli are considered to be an appropriate source of inspiration as they can support the development and change of the design idea (Cardoso and Badke-Schaub 2011). In these cases, it is possible to say that instructor’s and student’s external representations were stimuli. According to Goldschmidt (1995),

designer remembers the forms found in memory with the help of stimuli, which is called recall. Most of the recall activity is initially done mentally. In addition to that, recalling is done synchronously with an intuitive search for matching the problem in hand and stored images (Goldschmidt 1995). Knowledge stored in memory can be accessed with the help of stimuli. These stimuli can be external analogical sources. The knowledge obtained through these sources can be used to generate new ideas (Goldschmidt 1994). In this study, most of students recall new ideas through precedent. In other words, when both precedent and sketch are given in critique to the student, the student is more affected by the precedent. In this case, it is possible to interpret that student created a new idea or product through case based reasoning. This is due to many reasons, but one of these reasons is that the precedent is a clear expression of the critique. The student sees the form of the instructor's idea in the precedent and she/he tries to reflect this idea in her/his project. Sketch is a representation that has a different meaning for everyone. Therefore, it cannot be clear. Sketch creates a different perception in everyone, thus it allows to different conceptual space (solution space). Therefore, it is possible to interpret that students make mostly lateral transformation in critiques which sketch is given by instructors.

In these cases, the initial schemes are conceptually and/or formally transformed. These transformations took place differently in each case (Figure 73). At panel reviews, midterm juries, and desk critiques, instructors provided conceptual and procedural knowledge to the students. Students, in turn, designed new schemes with conceptual and procedural knowledge during the pictorial reasoning process. However, each student developed a product with different pictorial reasoning. When the pictorial reasoning processes of the students are examined, it is possible to say that each student follows a different process (Figure 74).

Transformations (lateral-conceptual, vertical-detail) and pictorial reasoning styles (seeing as, seeing that) occurred with different frequencies and following different paths in the process of each student. Student 1 arrived at a final scheme with four conceptual transformations (Figure 73). His pictorial reasoning style was mostly “seeing as” in this process (Figure 74). When Student 2 was examined, his final scheme was designed through two conceptual transformations (Figure 73). This student’s pictorial reasoning style was mostly “seeing that” (Figure 74). Student 3 transformed conceptually his project three times to reach his final scheme (Figure 73). His pictorial

reasoning style was “seeing that” at all steps (Figure 74). Lastly, Student 4 designed her final design through one conceptual transformation (Figure 73) and her pictorial reasoning style was mostly “seeing that” (Figure 74).

The reasons for these differences could vary from case to case (Figure 75). According to Goldschmidt (2005) and Schön (1985), the design process, after determining the problem, is shaped by designers through interpretations of the problem. However, the designer is not objective in this interpretation process. The reason for this is that any field-specific knowledge and skills are based on the ‘background knowledge’ that people have had in their previous education and life experiences. Moreover, each person has his or her ‘own notes’, which have their own cognitive and personal characteristics. These notes and knowledge shapes the design process. Individual differences, therefore, could be one of the reasons of different design processes observed in students’ design.

Design is shaped through interaction between designers in a particular design environment. However, each interaction between an instructor and a student via different media can produce different results because it occurs with different people, in different settings, and with different media. Especially in a design team, interaction between designers has an important role. In the design studio environment, instructor-student as a design team work together. A synthesis of existing knowledge and new learned knowledge emerges during instructor-student interactions. In other words, a new mental model emerges with shared mental models. In design process, the interaction of representations and shared mental models brings new knowledge and creative results (Rouse and Morris 1986). Especially in team work like as instructor-student, it is important to have teammates share their mental models with each other (Gentner and Stevens 1983). Each team member has her/his own mental model in a team. However, to be effective, the team needs to share mental models. Therefore, team members externalize their mental models to discuss their views and exchange their opinions (Goldshmidt and Surasky 2011). In team work, a common mental model is achieved by shared mental models (Langan-Fox, Anglim and Wilson 2004). Therefore, each design process is unique and does not follow a linear order. There are overlaps between design stages. Especially, in these cases, the final schemes emerge through synthesizing four different instructors’ personal and cognitive characteristics in addition

to students' own personal and cognitive characteristics. In other words, each student's projects were shaped with five different personal and cognitive characteristics.

When the rotation method applied in these cases is examined, it can be said that there are positive and negative aspects. On the positive aspect, students' designs benefit from four different instructors' personal and cognitive characteristics in addition to students' own personal and cognitive characteristics.

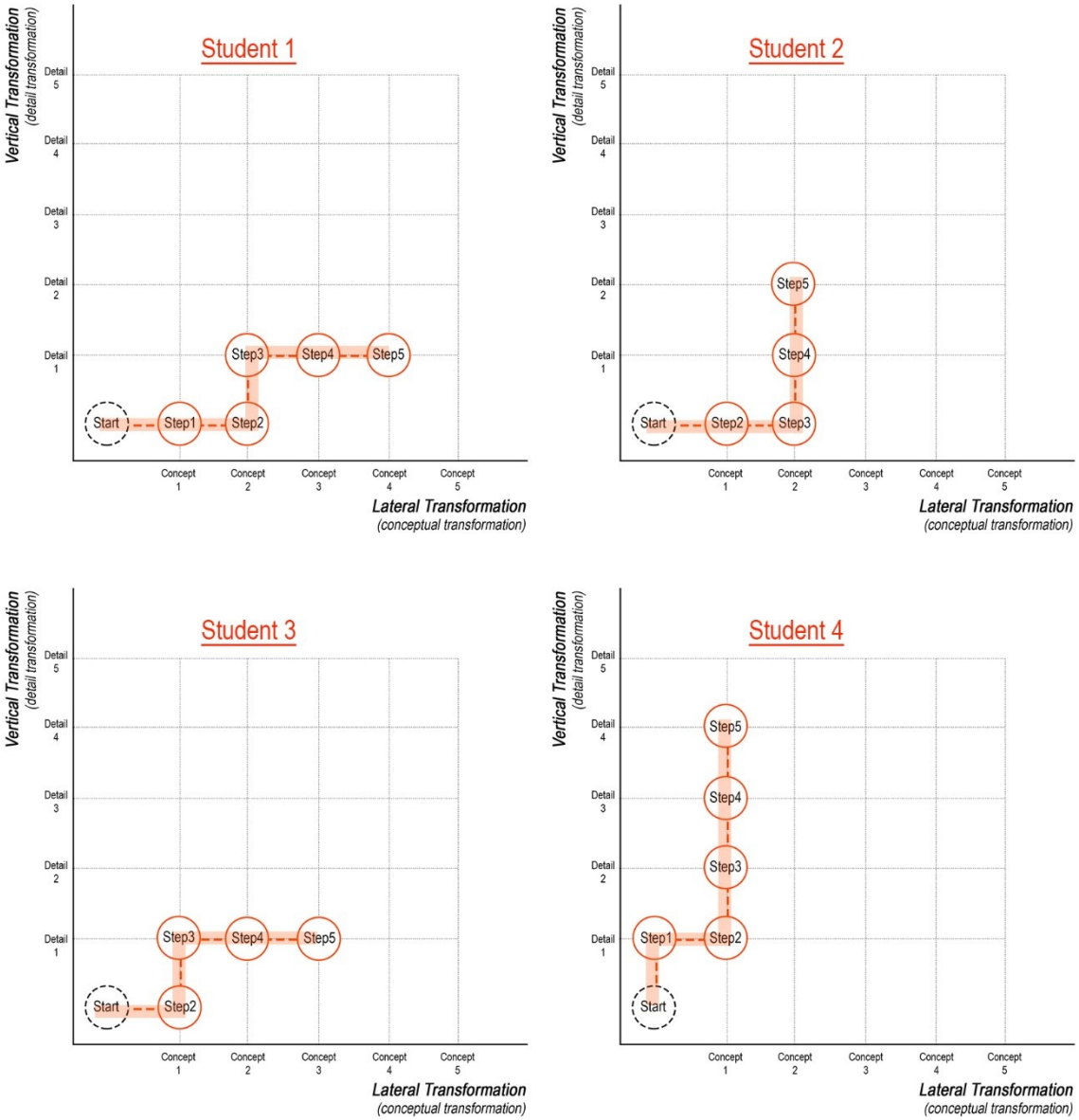


Figure 73: Transformation process of students

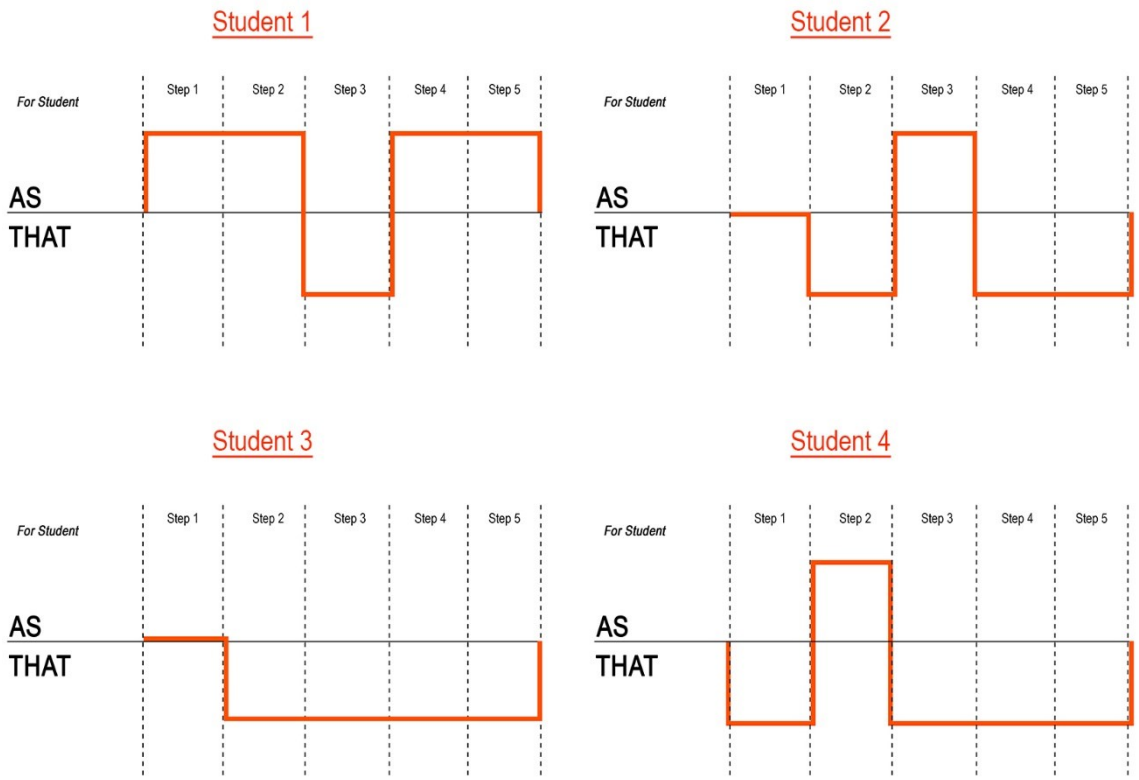


Figure 74: Pictorial reasoning process of students

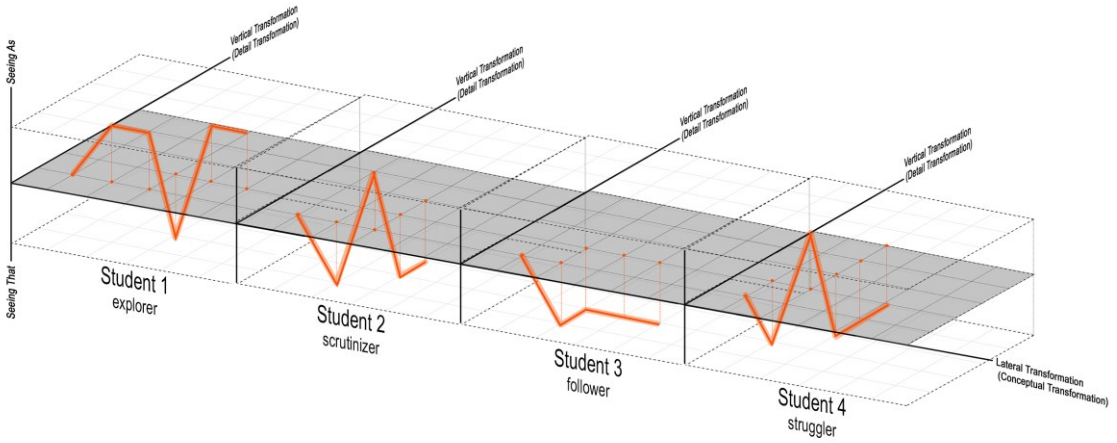


Figure 75: Design Path of students

This method has the potential to expand the conceptual space (solution space) of students and to avoid early fixations or strict and utmost control of a single instructor over students' projects. However, sometimes this situation may be different. In the process, the student or instructor may be the dominant. When the student is dominant, he or she can be fixed, stubborn, or scrutinizer. When the instructor is dominant,

students can have explorer, follower or submissive attitude. These possibilities may cause or block divergence in the process. However, in the learning process, lack of convergence is not a failure because this possibility provides more options for designers so, this might be good for creativity. If it is considered that studio learning is process rather than a product, this could be beneficial. On the other hand, this method can create confusion in the mind of the students and prevent them arriving at a solution at all. However, when everything is taken into consideration, instructors' awareness of the relationship between cognitive activity and design process can lead to more successful results in design learning.

Briefly, in this study, different processes were observed due to the nature of the design process and the cognitive characteristics of the individuals. Although the processes of students were different from each other, the common thing was “design learning”. It is possible to state that interactive imagery and shared mental models contributed to students’ design learning process through the learning of conceptual development.

CHAPTER 5

CONCLUSION

The aim of this thesis was to inquire into two questions: how interactive imagery facilitates construction of shared mental models in a design learning environment and how the interactive imagery that occurs in the desk critique process performed by more than one instructor through the rotation method affects the student's conceptual space (solution space)? To investigate the answers to these questions, different views of design were reviewed from design studies field. Initially, design definitions and different perspectives were presented. Some of the views included in the review were design as "problem solving process" (Newell and Simon 1972), as a "knowledge-based activity" (Coyne, et al. 1990), or as a "cognitive activity" (Akin 1986), or as "reflection-in-action" (Schön 1983).

The difficult and complex structure of design makes it difficult to learn and teach the design process. In design, learning activity is based primarily on 'learning-by-doing' (Schön and Wiggins 1992). According to Schön (1983), every profession has a body of special procedural knowledge (tacit knowledge). In design learning environment, instructors demonstrate this knowledge in action. According to Schön (1983), 'procedural knowledge' is acted on in the context of design studio, which he defines as a virtual world, through 'off-line' interactions of 'novice-coach'. According to Schön (1983) this learning style is defined as "reflection-in-action". Novice learns the procedural knowledge in this process. Experiences in this process are 'reflective practices' (Schön 1983). According to Uluoğlu (2000), design can be taught and learned through interaction between designers. Therefore, design is not just about "doing" an action. Design activity is based on cognitive abilities that foster reflection on action and on other reflections. This approach explains why design cannot be taught with existing knowledge and skills (Uluoğlu 2000). Goldschmidt (2005) argues that people acquired knowledge in their previous education and life experiences and any field-specific knowledge and skills are built on top of this body of knowledge. Moreover, each person has his or her own cognitive and personal characteristics (Goldschmidt 2005). When faced with a design task, the designer solves design problem by using this knowledge

and characteristics. Therefore, each person can create different solution spaces (conceptual space) in the design process.

In order to define, learn, and teach design, it is important to discover what is in the mind of the designer. The emergence of cognitive science in the 1960s suggested a method for both the identification of design and the study of mental activity occurring during the design process (Eastman 2001). Within the scope of the thesis, cognitive activities were examined under the cognitive components of design: representation and reasoning.

There are various studies in the literature on cognitive abilities and their relation to design learning and design process. According to Oxman (2001), some of these studies are "mental imagery and visual reasoning" (Kosslyn 1975), "analogical reasoning" (Holyoak and Thagard 1995), "remembering" (Schank and Abelson 1977), "visual design thinking" (Goldschmidt 1994), and "metaphorical reasoning" (Lakoff 1994). The design problem is solved by these skills, which are basically thinking, learning and reasoning, and by the tools supporting them. One of the most important tools in the problem solving process of design is to create a 'language'. At this point, representation plays a very important role. Representation is the basic component of this process both as a mental activity and as an externalization of this activity (Goldschmidt 2007). According to Akın (1986), there are two types of representation. One of them is external representation as stimuli. The other is internal representation that occurs in mind as the result of external and internal representations. Representation is not only a passive mechanism that externally displays what the mind contains, but it is actively guiding design (Akın and Moustapha 2004). In the design process, visual images or representations are a very effective tool for some reasoning types. Some of these reasoning are analogical reasoning (Gentner and Stevens 1983), case-based reasoning (Kolodner 1993), and pictorial reasoning (Gero, Tham and Lee 1991).

According to Oxman (2001), representation which is used in visual reasoning, can be an external representation that can be matched on to an internal representation and it makes the reasoning process possible. Goldschmidt (1991) argues that in pictorial reasoning, it is possible to directly access the knowledge contained in visual images. However, it is also possible to access knowledge that they do not expressly disclose (Goldschmidt 1991). In other words, different knowledge can be obtained by reasoning

with the help of visual images or representations, and different knowledge can be recalled from the memory.

Representations or visual images enable imagery in the design process. In this thesis, two types of imagery were explained: mental imagery and interactive imagery. According to Athavankar (1997), Arnheim (1969) states that mental imagery is one of the means of design thinking. Similarly, Mc Kim (1972) claims that mental imagery is part of visual thinking. Sommer (1978) refers to mental imagery as ‘mind's eye’ and he refers to 'mental imagery ability' as allowing conversions in mind. According to Goldschmidt (1991), imagery is the essence of seeing something as something else. If this happens in the sketch process, it is “interactive imagery” in the words of Goldschmidt (Goldschmidt 1991, 131). Imagery supports both knowledge recall and new knowledge inferences. In the design process, knowledge creation or knowledge recalling plays an important role. During the design process, there are stimuli that evoke visual images or conceptual knowledge from memory and make them active in memory. Stimuli which help creating new knowledge, new form, and new concept, can be recalled from long term memory. Stimuli serve as a source of inspiration for a new image. Stimuli can be an image, a word, or a sense. However, designers prefer to use visual sources because of its compatibility with visual simulation (Hanington 2003). These stimuli affect the mental models of people. Mental model is defined as an internal representation that provides to identify and predict objects, conditions, phenomenon, and people (Goldshmidt and Surasky 2011). Goldschmidt (2017) argues that people acts on the basis of mental models that guide behavior and thought. In the design environment, the mental models owned by each designer are transferred to each other by externalizations. The interaction of representations and shared mental models brings new knowledge and creative results (Rouse and Morris 1986).

In studies on design learning, Schön (1983) and Goldschmidt (2005) explain design learning through three main components. Especially in the studies on design studios, which are the fundamental learning environment, these components are defined as instructor, student, and representation (tool). According to these studies, design learning is shaped with these components.

The interaction of the three components shapes the design learning process together with cognitive abilities such as thinking, reasoning, mental and interactive

imagery. In this thesis, the role of these abilities in the process is investigated. This study examines four case studies in a design studio with more than one instructor to understand the construction of shared mental models through visual and verbal communication throughout the whole semester. It especially focuses on how a student's mental model of a design situation keeps changing or remains unchanged in a design studio where students take critiques from different instructors. Additionally, in this study, it is possible to interpret that different results have occurred due to the operation of the studio by the rotation method. In this method, the same student can create a different process with each instructor or it can be said that the same instructor has a different process with each student. In rotation method, the attitude of the student and post-critique products change from instructor to instructor. The student gets along better with some instructor and he/she develops his/her project based on the instructor's suggestions. Sometimes, the student only applies some instructors' suggestions to the project due to the course grade anxiety. In this method, many similar "cause-effect" interpretations can be made. Therefore, this study proposes a vocabulary about the student-instructor roles in the design studio in addition to the design learning process.

5.1. Implications of the Study

The insights gained from this research can contribute to the views about the design learning processes in the studio environment. Furthermore, this study can offer a different perspective to designers' views on the design process. Being aware of cognitive activities, sharing mental models, understanding the role of representations in guiding the process can contribute to design learning and teaching processes. In design studio environment, the realization of the interactive imagery and shared mental model can affect conceptual space (solution space) of the students. The information obtained from the research can reveal the cause of this situation. The interactive imagery that takes place during the design process, which is a cognitive activity, allows many different mental models. Desk critiques, juries, and panel reviews that take place in studios are processes in which interactive imagery takes place. Interactive imagery occurs with the help of representations which are presented and created in these processes. In this way, the mind of each designer is stimulated. New mental models occur through these stimuli. A learning environment is enhanced by sharing mental models.

In the case studies, the critiques were given by four instructors following a rotational order. It is possible that being exposed to different instructors would enhance interactive imagery. Potentially students' designs would benefit from four different instructors' personal and cognitive characteristics in addition to students' own personal and cognitive characteristics. In other words, each student's projects were shaped with five different personal and cognitive characteristics. Therefore, each design process is unique and also is not linear. This method has the potential to expand the conceptual space (solution space) of students and to avoid early fixations or strict and utmost control of a single instructor over students' projects. On the other hand, this method can create confusion in the mind of the students and prevent them arriving at design a solution at all. When everything is taken into consideration, instructors' awareness of the relationship between cognitive activity and design process can lead to more successful results in design learning.

5.2. Limitations

The study was made retrospectively. Therefore, all situations in the process could not be observed. All representations and their interpretations of the process could not be obtained. However, a great majority of the material was available and the personal memories were still fresh. The process was analyzed and interpreted with the data obtained from students and instructors interviews.

5.3. Future Work

Case studies in this thesis were made in a studio environment. It could possible to conduct a comparative study in which the interactive imagery at critiques of studios administered by one instructor is compared to one where there are multiple instructors. In addition, in the studio run with one instructor, the relationship between interactive imagery and shared mental models can be analyzed on its own. One could also conduct an ethnographic study through direct observations. Thus, more information and details about process can be obtained. Additionally, it could be possible to study the role of interactive imagery in constructing shared models in professional design teams.

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